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MARINE CHLOROPHYTA OF THE UPPER WEST COAST OF FLORIDA

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ABSTRACT

Sixty-five species of marine Chlorophyta are reported from the Florida Gulf coast between Tampa Bay and Pensacola, about half of which are newly reported for this area. A key, descriptions, and many illustrations are included.

INTRODUCTION

The marine algae of the upper west coast of Florida and the environmental factors influencing their distribution are the least known for any part of the long Florida coast line. Until recently, collections from the Gulf coast were remarkably few.

While Taylor's well-known *Marine Algae of Florida with Special Reference to the Dry Tortugas* (1928) is a most useful reference for determination of the Gulf coast algae, it does not include Gulf coast records as there were virtually none at the time. In a 1936 paper, however, Taylor listed several west coast records. In 1954, he published two papers on the algae of the Gulf of Mexico, one of which (1954a) includes Florida collections made by Drs. Francis Drouet, C. S. Nielsen and others during the winter of 1948-49. The other paper (1954) summarizes the limited knowledge of the marine algae of the Gulf of Mexico up to that date.

In 1960, Taylor's *Marine Algae of the Eastern Tropical and Subtropical Coasts of the Americas* was published. This comprehensive work includes nearly all records of marine algae known from the Gulf of Mexico up to the time it went to press. However, the list that follows includes six species not included in Taylor's work and additional species not previously reported for the Gulf of Mexico. About half of the 65 species listed below have not been reported previously from the area north of Tampa Bay.

With the establishment in 1949 of the Oceanographic Institute at Florida State University, facilities and stimulus were provided that

resulted in many collections in the Gulf, especially from offshore localities between Fort Myers and Pensacola. Among those who contributed to these collections were John Morrill, F. C. W. Olson, Robert H. Williams, Tim Smith, Marvin Wass, Luis Almodovar, Mike Castagna, George Grice, Mary Ann Olson and Heather Seay. Of special value were the collections made by Olson and Morrill in June, 1954, on a boat trip from Alligator Harbor to Bayport. The writers also made many collections, not only in shallow water but also by means of dredges and diving equipment in deeper water at a number of stations within the range with which this paper is concerned.

In view of the magnitude of the work required to study the available collections thoroughly, it was decided to limit this first report to the Chlorophyta only and to the upper west coast of Florida from Tampa Bay to Pensacola, the least known portion of the Florida Gulf coast.

In addition to the collections mentioned, records have been included from the literature and from herbaria, particularly those of Florida State University and Duke University. Herbarium specimens of all species listed that were determined by the writers have been deposited in the herbarium of Duke University.

Grateful acknowledgment for use of facilities and for assistance in collecting is made to Dr. E. Lowe Pierce of the University of Florida for the opportunity to use the facilities of the Seahorse Key Marine Laboratory; to Dr. Philip Butler, Director of the U. S. Fish and Wildlife Laboratory at Gulf Breeze near Pensacola, for use of facilities of that laboratory; to Mr. Winfield Brady of the "Gulfarium," Fort Walton Beach, for a small offshore collection; and to Mr. George Saunders for a trip on his trawler off Dunedin.

A General Foods Fellowship for research in marine algae provided the junior author the opportunity to devote all her research time to this work during the academic year 1955-56 in the Department of Botany, Duke University.

THE HABITAT

Topography. — The northern Gulf coast of Florida is characterized by an extremely wide continental shelf resulting in a very gradual seaward slope. The shelf is widest (up to 117 miles) between Tampa Bay and Apalachee Bay and becomes narrower westward, especially off Panama City and Pensacola. The shelf is composed mainly of limestone rock with a thin covering of sand and detrital sediment or muddy sand.

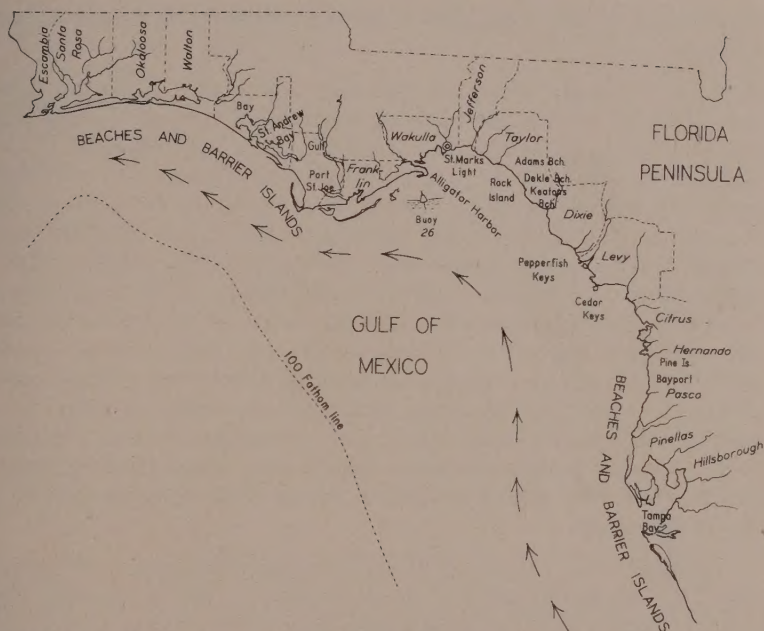


FIGURE 1. The coastline with which this study is concerned showing the location of the coastal counties, the major inshore current pattern, and the location of several important collecting stations. Between the two areas labelled "beaches and barrier islands" is a long stretch of coastline dominated by salt marshes where beaches and barrier islands are few and poorly developed.

Much of the coastline between Tarpon Springs and Apalachicola is composed of extensive salt marshes dominated by *Juncus roemerianus* Scheele or *Spartina alterniflora* Loisel or of forested swamps (Kurz and Wagner, 1957). *Spartina* occupies a slightly lower marsh than does *Juncus*. Most of the remainder of the coast is of narrow sand beaches, often with sand dunes behind the beaches. Because of these marshes, the coastal road is several miles or more inland and the coastline is relatively inaccessible. Side roads to the shoreline are few, and approach from seaward is possible only in vessels of shallow draft such as an outboard powered skiff.

Between Panama City and Pensacola there are about 50 miles of oceanic beach with the coastal road overlooking the Gulf. The sea bottom slope is relatively abrupt and the inshore waters are of offshore

characteristics with high salinity and remarkably clear and bluegreen in color.

Salinity. — Salinity affects only the local distribution of marine algae and is not a factor in their general distribution between Tampa Bay and Pensacola. There are many localities where high salinities (25‰ and above) occur inshore, and a good variety of algae is to be found, especially if rocks or some other suitable substrate are present. Off the mouths of small rivers and estuaries where salinity may fluctuate widely, the stenohaline species are to be found farther offshore. Since the depth may be but 25 or 30 feet a distance of 10 miles out, there is sufficient light penetration for a wide variety of species out beyond the significant influence of fresh water, and these will be found wherever the bottom is of such nature as to permit their development. There are many such localities with scattered shells, limestone protruding through the sand, and corals. Dredging at such a habitat is the easiest collecting procedure but the only really effective means of determining the algal population is by use of diving equipment such as the aqua-lung.

Temperature. — North of Tampa Bay the distribution of marine algae is only slightly affected by water temperature. In general, any species found as far north as Tampa Bay will be found around the entire shoreline of the Gulf with possibly a minor gap off the Mississippi river mouth. That this distribution pattern is the rule rather than the exception has not been understood previously because of the inaccessibility of the habitats of stenohaline species. Many of them are offshore where the salinity and temperature do not fall below their range of tolerance and only where a suitable substrate occurs. These are rarely found in the beach drift.

The major currents of the Gulf of Mexico which influence the distribution of attached marine algae along the west coast of Florida are shown for the month of December by Leipper (1954, fig. 35). The north-bound movement of warm water along the coast stabilizes the winter temperatures of inshore waters 25 to 200 feet in depth to such an extent that many species of algae found among the Florida keys may be expected north of Tampa Bay some distance offshore. The very shallow inshore waters between Tampa Bay and Pensacola respond more quickly to low winter air temperatures and thus they support genera and species common in cooler regions, or the more tolerant species with tropical affinities. For the most part, this shallow

inshore water covers a type of bottom that does not support a large variety of algae. Figure 1 shows the coastline with which this study was concerned, the coastal counties, the major current pattern of the winter months, the general nature of the coastal area, and the location of several of the major collecting stations.

Figure 2 is a composite of three "marine climographs" prepared by Dr. F. C. W. Olson formerly of the Oceanographic Institute, Florida State University. Although these indicate that the difference between the minimum winter temperature of inshore water at Key West and Pensacola is about 15 degrees, the temperature differential is actually less than this in areas along the northern Gulf coast occupied by

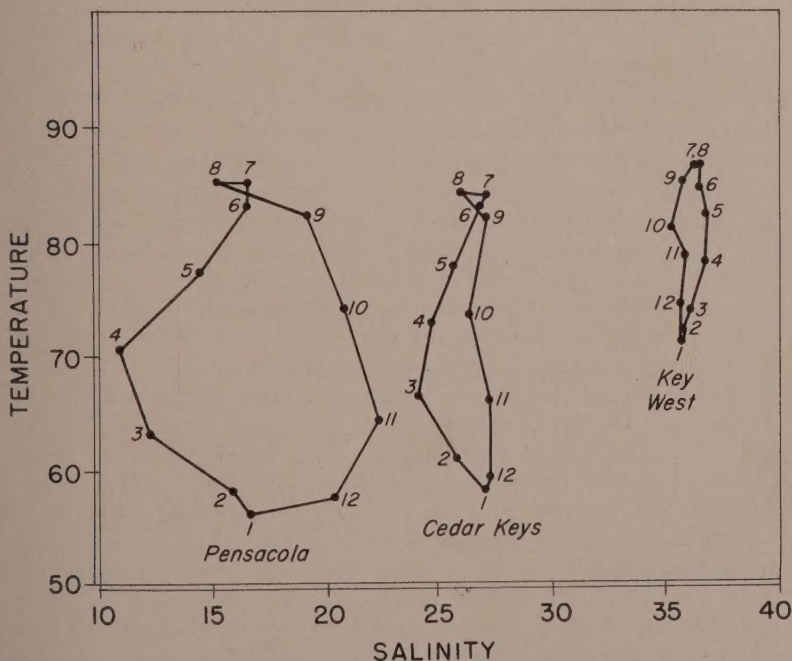


FIGURE 2. Marine climographs of three widely-separated Florida Gulf coast localities showing temperature (in degrees C.) and salinity (parts per thousand) of inshore waters for a period of one year. Numbers adjacent to dots represent months of the year. (Graph prepared from Coast and Geodetic Tide Station data by Dr. F. C. W. Olson, formerly of the Oceanographic Institute, Florida State University.)

marine algae of tropical affinities (Leipper, 1954; fig. 39). The similarities of winter temperatures between Cedar Keys and Pensacola are striking.

General Discussion — The conception that the marine algal vegetation of the northern Gulf coast is determined entirely by muddy shores and brackish water, and dominated by *Ulva*, *Enteromorpha*, *Rhizoclonium*, *Vaucheria*, *Bostrichia* and *Caloglossa* is true only of strictly shoreline localities. This impression has arisen as a result of fragmentary and fortuitous collecting of the past, often only of material that has washed ashore. That many additional species are to be found along the northern Gulf coast is indicated by the variety and newly established ranges of many green algae reported herein. A thorough knowledge of the distribution, variety and abundance of this flora will not be known until many more habitats are located in general by dredging or fathometer records, then studied in detail by means of diving equipment down to depths of at least 100 feet.

AFFINITIES OF THE FLORA

The tropical affinities of the marine Chlorophyta of the upper west coast of Florida are clearly in evidence in the list of species that follows. Among these, the principal indicators are members of the orders Siphonales, Siphonocladiales and Dasycladales, each of which is well represented. Additional members of these groups are certain to be found as more thorough collections are made.

Eight species of the genus *Caulerpa*, three each of *Halimeda* and *Udotea*, two each of *Acetabularia* and *Penicillus*, and one each of *Acicularia*, *Batophora*, *Dasycladus*, *Anadyomene*, *Cladophoropsis* and *Avrainvillea* are distinctly tropical. Of these only *Caulerpa prolifera* and two of the species of *Udotea* are known as far north as North Carolina along the Atlantic coast (Pearse and Williams, 1951) where the Gulf Stream exerts a strong temperature stabilizing influence in inshore waters as far north as Cape Hatteras.

Species present along the northern Gulf coast which are not principally tropical in distribution are eurythermal species of extensive latitudinal distribution, many of them extending from Canada or New England to the West Indies or Brazil. *Ulva lactuca*, *Enteromorpha clathrata*, *Rhizoclonium riparium*, *Cladophora gracilis* are examples of these.

COLLECTING STATIONS

Stations from which collections were made are shown in Figure 1.

Most collecting was done in shallow water and by means of a face mask. Dredges and air-supplied diving equipment were used in the vicinity of buoy 26, about 10 miles south of Alligator Harbor and around limestone patches 5 to 7 miles ESE of St. Marks Light off Wakulla County. A dredge collection was obtained from the vicinity of Panama City and a trawling trip was made off Dunedin, Pinellas County.

LIMITATIONS OF THE KEY

The following key to the species of green algae included in the list that follows was devised primarily for use as an aid in the identification of members of this group from the Cedar Keys area northward to Pensacola. The key should be used with special caution for collections obtained south of Cedar Keys to Tampa Bay, especially if the collections are from deeper water or offshore stations. The authors did not have an opportunity to collect as thoroughly at offshore localities south of Cedar Keys, and this area certainly supports many tropical *Chlorophyceae* not listed here (Phillips and Springer, 1960). Even in the area for which the key is intended, species of green algae which have not yet been reported are likely to be encountered.

KEY TO THE SPECIES

1. Plants with an erect and prominent main axis, usually in the form of a stalk, which differs from the branches or upper parts; plants often calcified2
1. Main axis creeping, if distinct from the branches; or if erect, not differing notably from the branches and not calcified; or, without a distinct main axis13
 2. Main axis and branches composed of cactus-like segments; calcified3
 2. Main axis not composed of cactus-like segments4
3. Largest segments 2-3 cm diameter; main axis not very different from branches, or without main axis*Halimeda discoidea*
3. Segments smaller; main axis a distinct stalk that differs from the upper branches*Halimeda incrassata*
 4. Base of plant (stalk or rhizoids) penetrating sand or mud5
 4. Base attached to stone or shell9
5. Stalk bearing a flat, fan-shaped blade6
5. Stalk bearing a tuft of loosely-united filaments8
 6. Blade soft, spongy; not calcified*Avrainvillea levis*
 6. Blade firm, leathery; somewhat calcified7
7. Blade smooth, the filaments of which it is composed having lateral branches terminally flattened*Udotea flabellum*
7. Blade composed of obvious filaments without special lateral projections*Udotea conglutinata*

8. Filaments 100-200 microns in diameter *Penicillus capitatus*
8. Filaments 400-500 microns in diameter *Penicillus lamourouxii*
9. Stalk with a flattened or concave disk on top 10
9. Most of stalk or all of it clothed with whorled, monosiphonous, dichotomously-branched ramuli 12
10. Segments of disk fewer than 30, lightly calcified; ends of segments obtuse or truncate *Acetabularia farlowii*
10. Disk segments more than 30, lightly calcified; ends of segments with a point or spine 11
11. Disk with 30-42 segments; 4-8 mm wide; stalk 1-3 cm high; spores not calcified, but embedded in a mass of calcium carbonate *Acicularia schenckii*
11. Disk with 35-60 segments; 6-18 mm wide; stalk 3-7 cm high; walls of spores calcified, not embedded in calcium carbonate *Acetabularia crenulata*
12. Branches closely attached to stalk and densely clothing it to the base *Dasycladus vermicularis*
12. Branches attached to stalk at about 1 mm intervals; stalk bare at base *Batophora oerstedii*
13. Plants with prominent, creeping main axis which bears upright branches and rhizoids at intervals 14
13. Plants otherwise 21
14. Upright branch a simple blade *Caulerpa prolifera*
14. Upright branches variously branched or divided 15
15. Ramuli pointed at tips 16
15. Ramuli spherical, disk-shaped, or elongate and obtuse at tips ... 19
16. Upright branches subdivided several times, aspect somewhat palm-like *Caulerpa paspaloides*
16. Upright branches not as above 17
17. Blade flat with flat, distichous ramuli often constricted at the base *Caulerpa crassifolia*
17. Ramuli not flattened 18
18. Ramuli in two ranks; slender, cylindrical and elongate *Caulerpa sertularioides*
18. Erect branches dichotomously branched with conical, compressed, or cylindrical ramuli in two, three or more ranks .. *Caulerpa cupressoides*
19. Erect branches, 3-5 inches tall; ramuli terete, elongate, distichous *Caulerpa ashmeadii*
19. Ramuli swollen to spherical or peltate; often in dense masses 20
20. Ramuli disk-like, on short pedicels *Caulerpa peltata*
20. Ramuli swollen, elongate to spherical *Caulerpa racemosa*
21. Plant large, rope-like, dichotomously branched; structurally of many closely-united filaments 22
21. Plant not as above 25
22. Plant very dark green, rigid, densely branched with short internodes, dichotomous to cervicorn *Codium taylori*
22. Plant light to dark green, soft, internodes often several inches long, branching dichotomous 23
23. Main branches usually less than .5 cm in diameter. *Codium repens*
23. Main branches exceeding .5 cm in diameter 24
24. Peripheral utricles mostly 250-300 microns in diameter, the end walls considerably thickened *Codium isthmocladum*

24. Branches often flattened below the dichotomies; utricles usually 300-400 microns in diameter, the end walls not thickened. . . *Codium decorticatum* 26
25. Plants monosiphonous, coenocytic 29
25. Plants otherwise 29
26. Penetrating limestone, microscopic, filaments irregular in form, variable in diameter *Ostreobium quekettii* 27
26. Not embedded in limestone 27
27. Branching dichotomous *Derbesia vaucheriaeformis* 28
27. Branching irregular or pinnate 28
28. Plants partially embedded in soft mud; branching irregular *Vaucheria thuretii* 28
28. Erect branches bearing distichous or secund ramuli . . . *Bryopsis pennata* 30
29. Plant composed of a flat sheet 30
29. Plants otherwise 34
30. Cells visible without magnification, showing a delicate pattern of "veins" *Anadyomene stellata* 31
30. Cells alike and too small to be seen without magnification . . . 31
31. Sheet two cells thick 32
31. Sheet one cell thick *Monostroma oxyspermum* 32
32. Sheet divided into linear segments *Ulva fasciata* 32
32. Sheet entire, broad and irregular in shape, sometimes lobed; or linear lanceolate and without lobes 33
33. Sheet broad, irregular in shape, sometimes lobed, sometimes with perforations *Ulva lactuca* 33
33. Sheet lanceolate or linear-lanceolate, without lobes, unbranched, the margins hollow as a result of separation of the two cell layers *Enteromorpha linza* 34
34. Plant an elongate, branched or unbranched hollow tube, often flattened, the walls one cell layer thick 35
34. Plant not as above 43
35. Cells not in longitudinal rows except in youngest parts 36
35. Cells more or less in longitudinal rows throughout 38
36. Unbranched 37
36. Branched, sometimes sparingly or at base only; branches attenuate from base to apex, cell walls thin *Enteromorpha linguata* 37
37. Tubular throughout, usually inflated and irregularly constricted, often large *Enteromorpha intestinalis* 37
37. Flattened, the cell membranes adherent (as in *Ulva*) except at the margins where minutely hollow, lanceolate or linear-lanceolate *Enteromorpha linza* 38
38. Unbranched or branched sparingly at base only *Enteromorpha flexuosa* 38
38. Plant considerably branched 39
39. Plants small, slender, with thorn-like branches often opposite, the cells 14-16 microns in diameter *Enteromorpha salina* 40
39. Plants without short, thorn-like branches 40
40. Plants large, branching proliferous, similar to the main axes *Enteromorpha prolifera* 41
40. Branches of several orders, tapering from base to apex 41
41. Small branches ending in a monosiphonous tip . . . *Enteromorpha clathrata* 42
41. Branches not ending in a monosiphonous tip 42
42. Chromatophore filling face of cell; main axes with many long spine-like ramuli *Enteromorpha ramulosa* 42

42. Chromatophore not filling face of cells and having a net-like appearance; main branches repeatedly branched without distinct ramuli *Enteromorpha clathrata*
43. Plant small, not over 1 mm high if filamentous44
43. Plant filamentous, usually several cm in height or length, branched or unbranched, attached or loose56
44. Cells embedded in globose or flattened gelatinous matrix, well-separated *Pseudotetraspora antillarum*
44. Cells not as above45
45. Plant a disk or membrane of united filaments or of creeping, separated filaments; no distinct erect filaments46
45. Plant with distinct erect filaments, either scattered or in a dense mass53
46. Plant with a central membrane, often quite extensive, with free filaments extending from the edges; typically in Bryozoa and sponges *Entocladia flustrae*
46. Plant forming a flat, radiating disk, an irregular incrustation of cells, or creeping; branched filaments separate from each other; on shells, rocks or other algae47
47. Plant a microscopic disk of radiating filaments48
47. Plant composed of creeping, branched filaments, or the cells forming an irregular, monostromatic layer49
48. Disk becoming more than one cell thick at center, monostromatic at margins; no colorless hairs; marine, usually below low tide *Ulvella lens*
48. Disk monostromatic, the cells tall (elongated vertically) at center, flattened at the margin; colorless hairs occasional on young cells; often in brackish water, often intertidal *Pringshiemella scutata*
49. Plant penetrating shells or limestone, of irregular, branched filaments, swollen sporangia *Gomontia polyrhiza*
49. Plants not penetrating shells or limestone50
50. Cells forming a monostromatic layer or irregular cells, typically high intertidal, and producing a green zone on rocks and hardwoods *Protoderma marina*
50. Plant a creeping, branched filament51
51. Some cells producing erect, zig-zag or slightly spiralled, colorless hairs *Phaeophila dendroides*
51. Without colorless hairs52
52. Cells mostly cylindrical, averaging 9 microns in diameter, 1-1.5 diameters long *Entocladia wittrockii*
52. Cells irregular, averaging about 6 microns in diameter, 1-6 diameters long *Entocladia viridis*
53. Plant an irregular crust, pseudoparenchymatous, with occasional short erect branches; usually intertidal and often in brackish water *Pseudoendoclonium submarinum*
53. Plant composed of an erect filament or producing many erect filaments54
54. Plant with a basal layer of irregular cells giving rise to densely-placed, erect, often-branched filaments, some with terminal hairs *Pilinia rimosa*
54. Plant a single, erect, unbranched filament55

55. Filaments 5-6 microns in diameter, chromatophore usually covering more than half face of the cell; basal cell unmodified *Stichococcus marinus*
55. Filaments 7-10 microns in diameter, chromatophore usually covering more than half the face of the cell, basal cell modified *Ulothrix subflaccida*
56. Profusely branched 62
56. Unbranched, or with a few short rhizoidal branches 57
57. Filaments 80-300 microns in diameter 58
57. Filaments less than 80 microns in diameter 60
58. Filaments forming a loose, entangled mass 59
58. Filaments forming a clump of attached plants, 125-250 microns diameter *Chaetomorpha aerea*
59. Filaments 80-175 microns diameter *Chaetomorpha brachygona*
59. Filaments 180-300 microns diameter *Chaetomorpha linum*
60. Filaments 15-30 microns diameter, rarely with rhizoid-like branches *Rhizoclonium riparium*
60. Filaments less than 15 microns in diameter 61
61. Filaments 12-14 microns diameter, cells 1-2 diameters long *Rhizoclonium kochianum*
61. Filaments 10-14 microns diameter, cells 3-7 diameters long *Rhizoclonium kochianum*, var. *kernerii*
62. Ultimate branches usually without a crosswall at the base; filaments 180-250 microns in diameter *Cladophoropsis membranacea*
62. Ultimate branches with cross-walls at base 63
63. Main filaments usually over 150 microns diameter 64
63. Main filaments usually less than 150 microns diameter 66
64. Ultimate branches typically of 13 cells, 50-75 microns diameter, 1-2 diameters long, tapering sharply *Cladophora brachyclona*
64. Ultimate branches otherwise, the cells usually more than two diameters long 65
65. Ultimate branches in fasciculate groups, usually over 75 microns diameter, typically a plant of wave-beaten rocks; a deep water form has slender ramuli 20-30 microns dia. *Cladophora fascicularis*
65. Main axes and ultimate branches of about the same diameters; wiry dark green, typically in deep water and high salinity *Cladophora fuliginosa*
66. Main filaments less than 60 microns diameter, the ultimate branches 20-30 microns diameter 67
66. Main filaments usually over 75, the ultimate branches over 40 microns diameter and typically in second series; in salt marshes, often intertidal but also in deeper water *Cladophora gracilis*
67. Filaments soft, cells of ultimate branches usually 1-3 diameters long *Cladophora delicatula*
67. Filaments relatively rigid for their size, and glassy; cells of ultimate branches 3-4 diameters long or longer *Cladophora glaucescens*

GLOSSARY

acute—ending in a sharp point

akinet—asexual reproductive cell formed by the thickening of the wall of a vegetative cell

antheridium—structure producing male gametes

apical—at the apex or tip

- brackish water—a mixture of at least one-third fresh water and two-thirds, or less, sea water
- calcified—impregnated with calcium carbonate
- cervicorn—branching one-sided, suggesting the horns of a deer
- chromatophore—pigment-containing body of a plant cell
- clavate—club-shaped
- coenocytic—not divided into cells; a filament without cross-walls
- cordate—heart-shaped
- cortex—the outer layers of cells of a branch or axis
- compressed—flattened
- corticated—having a cortex; outer layer or layers of cells covering those produced directly by the growing point
- cross-wall—the end-wall of a cell of a filament
- deciduous—falling off naturally
- determinate—not growing beyond a certain size
- dichotomous—branched by forking into two equal branches
- dioecious—the sexes separate in different plants
- distichous—arranged in two rows or ranks
- endophytic—growing within the tissue or sheath of another plant
- epiphytic—growing upon the surface of another plant
- falcate—sickle-shaped
- fasciculate—a cluster of parallel filaments, stems, or branches
- fastigiate—tapering to a point
- filament—a plant or branch composed of a single row of cells
- filamentous—composed of one or more filaments
- internode—the region between two nodes; in a filament the part of a cell between the end walls
- intertidal—occurring between low and high tide
- lanceolate—lance-shaped; broad in the middle and narrow at each end
- linear—narrow and several times longer than wide with an abrupt taper
- moniliform—deeply constricted at regular intervals or at the nodes and hence resembling a string of beads
- monosiphonous—consisting of a single row of cells
- monostromatic—consisting of a single layer of cells
- node—in a filament the location of an end wall; a joint
- obovate—ovate but broadest at the outer end
- obtuse—with a blunt or rounded end
- orbicular—flat with a circular outline
- parenchymatous—tissue composed of thin-walled cells rectangular or polyhedral in shape; not filamentous
- parietal—just inside the cell wall; not in the center
- pedicel—a small supporting stalk
- peltate—disk-shaped and having a stalk fastened at the center
- penultimate—next to the last
- peripheral—at the edge
- pinnule—a branchlet of a distichous series
- proliferous—producing many adventitious branchlets
- pseudoparenchymatous—filamentous in origin but the filaments resembling parenchyma tissue
- pyrenoid—a small rounded colorless body in a chromatophore functioning as a center of starch accumulation
- pyriform—pear-shaped
- ramulus—a final branch

reniform—kidney-shaped

rhizoid—a one to many-celled filament serving as an organ of attachment

secund—bearing appendages in a row along one side of a branch

sessile—attached without a stalk

sporangium—a cavity in which spores are formed

stolon—a creeping stem

terete—cylindrical; round in cross-section

tomentose—densely hairy

trabeculae—slender strands or bars extending across the center of a cell or coenocyte and lending rigidity to it

truncate—more or less squared off at the end

uniseriate—composed of a single row of cells

utricle—the swollen end of a filament forming a cortical stratum at the surface

whorled—surrounding a branch in a ring

zoospore—asexual motile reproductive cell

SPECIES DESCRIPTIONS

Order ULOTRICHALES

Ulothrix subflaccida Wille

Figure 3A

Plant an unbranched filament 5-25 microns in diameter attached by a rounded basal cell; cells 1-2 diameters long, chromatophore band-shaped, parietal, with one or more pyrenoids.

The two collections upon which this record is based were characterized as follows: Cells 5-8 microns in diameter, 1-3 diameters long (mostly 2-3, but occasional cells of less than one diameter and up to four were seen). Chromatophore a parietal band, irregular, often with slender lobes, not filling the face of the cell but covering more than half of it. Reproductive cells 7-10 microns in diameter. Both zoosporangia and akinetes were present, the former with 8 zoospores. Filaments of many cells, about 500 microns long, attached by a small, subglobose basal cell.

Habitat.—On the stem of an old hydroid in 40 feet of water about 12 miles offshore, December; on oyster shells in Alligator Harbor, January. A record from Cuba (Humm and Jackson, 1955) formed a fine green fuzz on stones in the surf, February. All three records are from winter collections and from water with a salinity exceeding 30‰.

N.W. Florida.—Dredged in 40 feet of water near buoy 26 about 12 miles S.E. of Alligator Point, and in Alligator Harbor, Franklin County.

References.—Collins 1909; p. 186 (Collins discussed the problem

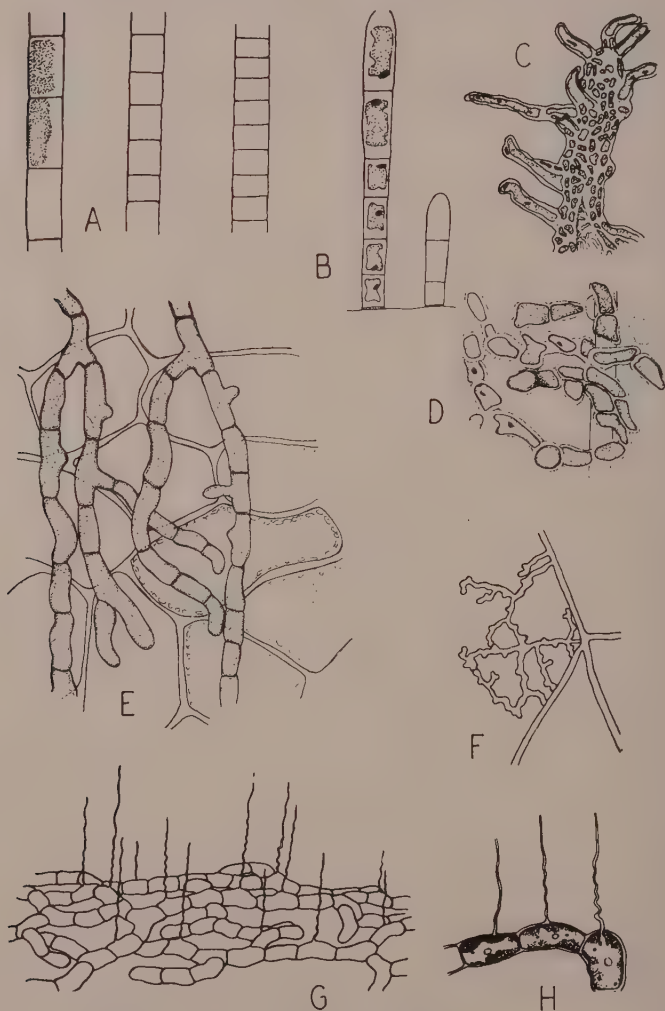


FIGURE 3. A. *Ulothrix subflaccida*, portions of three filaments showing variation in cell length. X 163. B. *Stichococcus marinus*. X 1500. C. *Entocladia flustrae*, the erect portion of a plant. X 163. D. *Entocladia flustrae*, filaments creeping on a sponge. X 180. E. *Entocladia viridis*, filaments creeping on a host plant. X 270. F. *Ostreobium quekettii*, from a decalcified shell. X 200. G. *Phaeophila dendroides*, part of a well-developed plant. X 80. H. *Phaeophila dendroides*, enlarged portion showing insertion of spiral hairs. X 150.

of separating genera of the Ulotrichaceae, p. 182); Humm and Jackson 1955.

Stichococcus marinus (Wille) Hazen

Figure 3B

Plant an unbranched filament 5-6 microns in diameter without a modified basal cell; cells 1-2 diameters long, chromatophore a parietal disk not covering more than half the face of the cell, with one pyrenoid. Asexual reproduction by biciliate zoospores without an eye spot, formed singly in a cell. One marine species.

Material referred to this species seen by the writers produced filaments only 20-75 microns tall, 4.5-7.5 microns in diameter, and composed of only 3-6 cells, the cells 1.5-3 diameters long with chromatophores that occupied somewhat more than half the face of the cell. The basal cell was unmodified except for a thicker bottom wall. The species seems to be present the year around (although summer collections are more common) and seems to extend considerably farther south along the Florida Gulf coast than *Ulothrix*.

A critical study of members of the family Ulotrichaceae of Florida waters is needed before it can be decided whether or not material dealt with here should be referred to species originally described from cold water or to others.

Habitat.—In N. W. Florida evidently intertidal, often in more or less brackish water, and year-around.

General Distribution: Northern Europe, New England, California, Florida (?).

N. W. Florida.—Evidently continuous from Cedar Keys to Pensacola. Since a collection has been obtained at Venice, indications are that it occurs along the entire Gulf coast of Florida.

References.—Collins 1909; p. 1909; Madsen and Nielsen 1950.

Family CHAETOPHORACEAE

Pilinia rimosa Kützinger (?)

Figure 4H, I

Plants with creeping basal filaments forming a pseudoparenchymatous layer one or more cells thick giving rise to crowded erect filaments about 0.4-0.5 mm high, sparingly branched, 6.5-9.0 microns in diameter, the cells 1-2 diameters long. Filaments with slight constrictions at the nodes and frequently terminating in a long, colorless

hair. Branching irregular, predominantly at the upper third of the erect filaments. Chromatophores completely filling the face of the cell, apparently with two pyrenoids. Sporangia either terminal on erect filaments or sessile on the basal layer (Newton, 1931).

A single collection of this material was made along the Florida Gulf coast from islands off Taylor County where it formed a fine, green fuzz on *Gelidium corneum* (Hudson) Lamouroux which grew in shallow water below low tide. Only one sporangium was seen in this collection and it was sessile on the basal layer, ovate, about 13 by 16 microns, apparently immature.

Whether the Florida collection represents an undescribed species or whether it should be referred to a known species is difficult to decide with the limited amount of material available. It was felt that the more conservative solution was the better one and that *P. rimosa* was the species most likely to represent the Florida collection.

Collins (1909) lists *P. rimosa* from intertidal woodwork in Maine where it formed a stratum just above a band of *Calothrix pulvinata* with the two plants mixed at the juncture of these strata. Collins' dimensions of cells and filaments are in good agreement with the Florida material; however, he does not mention the presence of terminal hairs, and these were common on the Florida material. Collins' *P. rimosa* was also restricted to a certain band of the intertidal zone and the Florida material was below low tide and epiphytic.

Newton (1931) lists *P. rimosa* as the only species reported for the British Isles. While Collins indicates that the reproduction was unknown (1909), Newton reports and figures sporangia either terminal on the erect filaments or sessile on the basal layer, and figures some of the erect filaments with terminal hairs. Newton, however, gives the dimensions as "vegetative cells 5-8.5 rarely 9.5 microns long, diameter equal to twice the length." Thus cell dimensions of British *P. rimosa* are markedly different from the dimensions of Maine and Florida material. However, Newton's figure does not bear out these dimensions. The erect filaments in her Figure 46A are about 4 mm wide (10 microns) and the cells are mostly isodiametric, a few longer than wide, in better agreement with Maine and Florida *P. rimosa* than with the dimensions given.

Habitat.—A single collection formed a green fuzz on *Gelidium corneum* from below low tide, rock islands off Taylor County, June 4, 1954, collected by F. C. W. Olson and John Morrill.

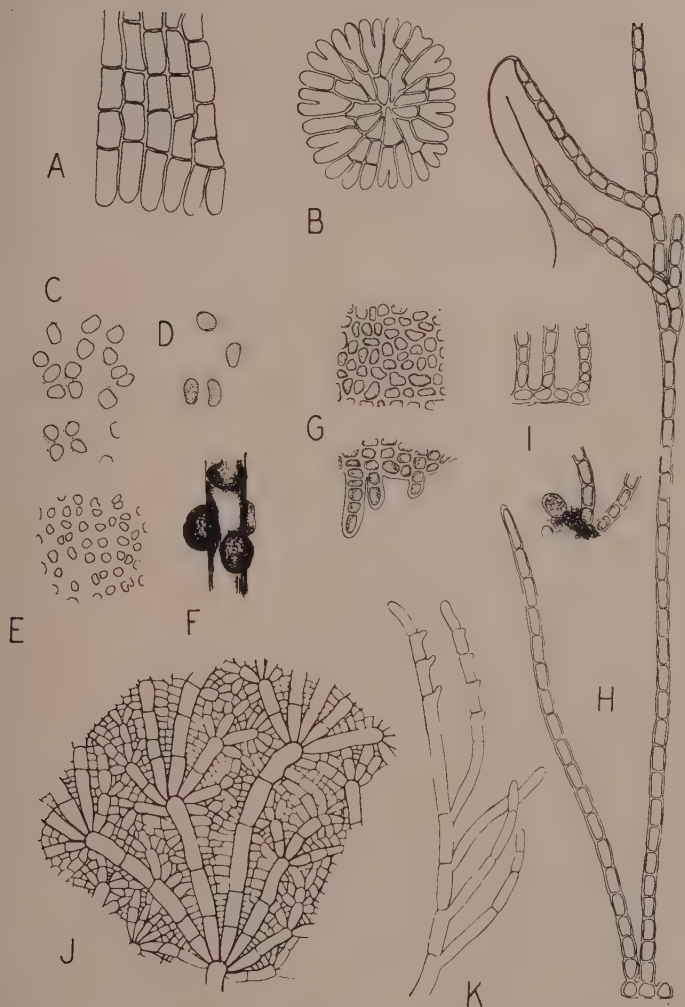


FIGURE 4. A. *Ulvella lens*, margin of a large plant. X 690. B. *Ulvella lens*, a small plant. X 560. C-F. *Pseudotetraspora antillarum*. Cells in surface view, X 342, X 405, X 200; and plants attached to a leaf of *Cymodocea manatorum*, X 1.9. G. *Protoderma marinum*, central and marginal portions of a colony. X 250. H-I *Pilinia rimosa*, habit of erect filaments and basal portions, once with a young sporangium. X 220. J. *Anadyomene stellata*, portion of a plant in surface view. X 8.2. K. *Cladophoropsis membranacea*, branch tips showing absence of crosswalls at their origin. X 16.

General Distribution.—New England, British Isles, Sweden.

References.—Collins 1908; 1909, p. 291; Taylor 1957, p. 48; Newton 1931, p. 60; Kylin 1949, p. 32.

Entocladia flustrae (Reinke) Batters

Figure 3C, D

Plant microscopic, of irregular and densely branching filaments which when well-developed form a central membrane with filamentous margin. Typically on the surface of Bryozoa. Chromatophore parietal with one pyrenoid. Central cells irregularly polygonal, usually 7-12 microns in diameter, occasionally larger.

General Distribution.—Greenland to New York, Europe, Florida.

N. W. Florida.—On Bryozoa from buoy 26, 10 miles S. E. of Alligator Point, Franklin County; from a sponge on limestone rocks in about 10 feet of water about 6 miles E. S. E. of St. Marks Light, Wakulla County.

References.—Collins 1909, p. 287; Newton 1931, p. 62 (both as *Epicladia flustrae*); Taylor 1957, p. 55.

Entocladia viridis Reinke

Figure 3E

Plant microscopic, of irregular, branched filaments 3-8 microns in diameter, creeping upon the surface of the host plant or within the gelatinous coating of the host. Cells 1-6 diameters long, usually irregularly swollen and contorted, with a single pyrenoid.

Habitat.—In the gelatinous coating of a wide variety of algae, in the tunic of ascidians, and elsewhere.

General Distribution.—Europe, New England to Florida, West Indies, Gulf of Mexico (entire coastline).

References.—Collins 1909, p. 279 (as *Endoderma viride*); Taylor 1957, p. 54; 1960, p. 50.

Entocladia wittrockii Wille

Plant microscopic, of irregularly branched filaments 5-10 microns in diameter, creeping upon the surface or within the gelatinous coating of the host plant. Cells cylindrical, 1-1.5 diameters long, with a single pyrenoid.

Habitat.—In New England it is usually found in brown algae, occasionally in red algae.

General Distribution.—New England, Florida?

N. W. Florida.—A single collection in the walls of the older portion of *Polysiphonia* dredged in about 40 feet of water near whistle buoy 26, about 12 miles S. of Alligator Point, Franklin County, January 31, 1953.

References.—Collins 1909, p. 279; (as *Endoderma wittrockii*); Taylor 1957, p. 54.

Pseudoendoclonium submarinum Wille

Plant of irregularly branched filaments packed together in a pseudoparenchymatous layer, with short erect branches and very short rhizoids. Cells irregularly rounded in shape, 6-7 microns in diameter, the chromatophore a small parietal disk with one pyrenoid. Asexual reproduction by akinetes and by 4-flagellate zoospores.

Habitat.—Usually high intertidal and often in more or less brackish water on woodwork, stones.

General Distribution.—Europe, New England, N. Florida Gulf coast.

N. W. Florida.—Inclusion of this species here is based upon its report by Nielsen and Madsen 1948, from Club Spring near Newport, Wakulla County. While this is presumably fresh water, its presence here would suggest that it also occurs along the coast at least in brackish water.

References.—Collins 1909, p. 284; Taylor 1957, p. 55; Nielsen and Madsen 1948.

Pringsheimiella scutata (Reinke) Schmidt and Petrak

Plant a monostromatic disk 1-2 mm in diameter on the surface of other algae, the marginal cells flat, the central cells tall; chromatophore plate-like with a single pyrenoid. Cells near center of disk producing 4-flagellate zoospores about 15 microns in diameter or 4-flagellate gametes about 4 microns in diameter.

General Distribution.—Greenland to New England, Europe, Bermuda, Jamaica, Florida.

N. W. Florida.—From fresh water (brackish?) stream, Leon County.

References.—Newton 1931, p. 65; Collins 1909, p. 288; Taylor 1957; 1960, p. 51. Nielsen and Madsen 1948a.

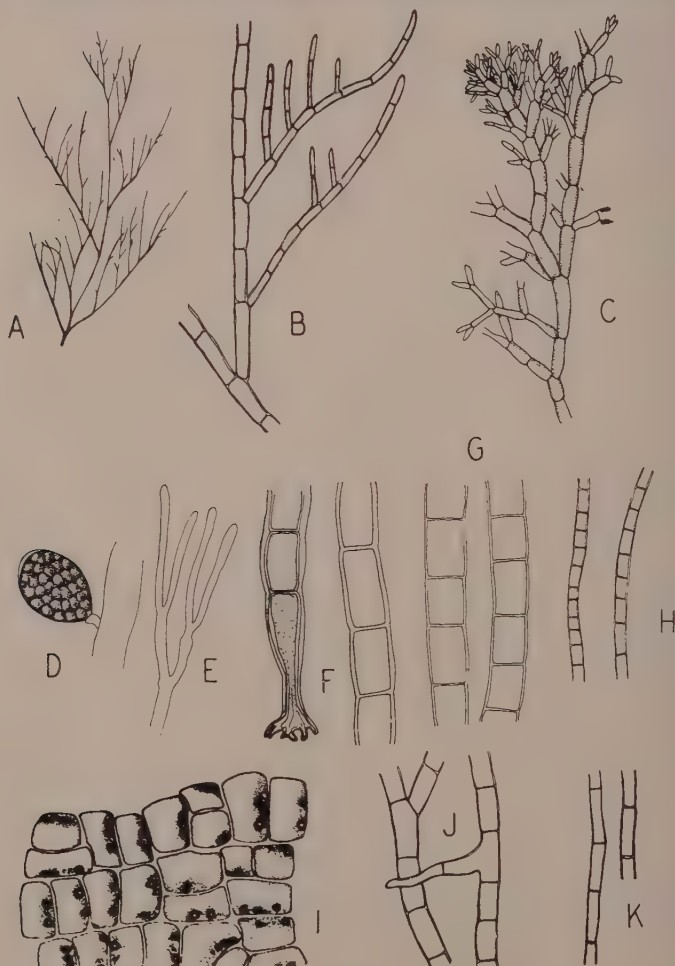


FIGURE 5. A-B *Cladophora gracilis*, habit of a portion of a plant (X 1.4) and a more enlarged portion showing second branchlets (X 28). C. *Cladophora branchyclona*, habit of a part of a plant. X 9. D-E. *Derbesia vaucheriaeformis*, a sporangium (X 45) and a branch tip showing dichotomies (X 28). F. *Chaetomorpha aerea*, the basal cell and a few cells from the central part of the filament. X 33. G. *Chaetomorpha linum*. X 19. H. *Rhizoclonium kochianum*. X. 133. I. *Enteromorpha clathrata*. X. 222. (After Bliding 1944.) J. *Rhizoclonium riparium*, portions of filaments showing a rhizoid and a branch, both apparently rare in Florida material. X 133. K. *Rhizoclonium kochianum*, variety *kernerii*. X 133.

Phaeophila dendroides (Crouan) Batters

Figure 3G, H

Plant of microscopic filaments, epiphytic or endophytic, branched, creeping on larger algae, shells and sea grasses, horizontal except for colorless, zig-zag or slightly spiral hairs produced by some of the cells. Cells 9-40 microns in diameter, 15-50 microns long.

General Distribution.—Europe, New England, Bermuda, West Indies, Florida.

N. W. Florida.—Continuous along the entire Gulf coast and common, usually on larger algae.

References.—Taylor 1928 (as *Phaeophila floridearum* Hauck); Newton 1931, p. 58; Taylor 1957, p. 51; 1960, p. 48, pl. 2, fig. 4.

Protoderma marina Reinke

Figure 4G

Plant a minute disk or forming extensive coating on rocks, firmly attached. Cells 5-12 microns in diameter, polygonal by mutual pressure except at the margins where short, radiating filaments may be produced.

General Distribution.—Europe, New England to Florida, Bermuda.

N. W. Florida.—Forming a green band at the high tide line and above in the splash zone, rocks of the breakwater near St. Marks Light, Wakulla County.

References.—Collins 1909, p. 217; Taylor 1928, p. 59; 1957, p. 58.

Ulvella lens Crouan

Figure 4A, B

Plant forming a disk 0.1 to 1.0 mm in diameter of closely-appressed, radiating filaments mostly 2-5 (to 6) microns in diameter and elongate-rectangular in shape (occasionally square), 5-12 (to 20) microns long, the marginal cells sometimes forked. Disk monostromatic in the radiating portion, but several cells thick at the center where the cells are irregular in arrangement, as seen from above, and more or less rounded. Central cells of larger plants to about 10 microns in diameter. Chromatophore a parietal disk filling the entire upper face of the cell. Plants epiphytic (larger algae and sea grasses), epizoid (ascidians, barnacles), or on stones and shells.

A discussion of the confusion concerning dimensions of the cells of *Ulvella lens* and a suggested treatment is given by Humm and Caylor 1957.

General Distribution.—Europe, North Carolina to Florida, West Indies, Caribbean Sea, Gulf of Mexico.

N. W. Florida.—Probably continuous along the entire Gulf coast.

References.—Taylor 1928, p. 59; Collins 1909, p. 286.

Family PLEUROCOCCACEAE
Pseudotetraspora antillarum Howe
Figure 4C-F

Plant a small, globular or flattened gelatinous mass attached to other algae or various substrata, usually 2-20 mm in diameter, yellowish brown, soft. Cells somewhat spaced in the gelatinous material, mostly 3-7 microns in diameter, globuse or ellipsoid.

General Distribution.—Previously known only from the Bahamas, the type from Rose Island.

N. W. Florida.—Off Wakulla and Dixie counties in 1-10 feet of water on larger algae and sea grasses (Pepperfish Keys area). Collected by John Morrill and F. C. W. Olson.

Reference.—Howe 1920, p. 597.

Family GOMONTIACEAE
Gomontia polyrhiza (Lagerheim) Bornet + Flahault
Figure 9E

Plants penetrating shells or limestone, filaments branched, 4-8 microns in diameter; sporangia produced at the surface, 30-40 microns in diameter.

General Distribution.—Europe, Canada, New England to Florida, West Indies.

N. W. Florida. — In *Busycon* shell near St. Marks light, Wakulla County; Municipal wharf, Cedar Key (Drouet and Nielsen). Probably common along the entire Gulf coast.

References.—Newton 1931, p. 96; Collins 1909, p. 370; Taylor 1957, p. 59 (including a summary of doubts expressed concerning the identity of this taxon).

Order ULVALES

Family ULVACEAE

Genus *Enteromorpha* Link, 1820

Plants tubular, branched or unbranched; cells with a single parietal chromatophore at the outer wall of the cell, uninucleate, one pyrenoid. In some species the tips of the branches may be solid or composed of a single row of cells.

The Genus *Enteromorpha* is notable for its taxonomic difficulty. The degree of variation of the vegetative characters upon which species are separated is not well known and the relative value of these characters has not been assessed. A monograph of the species of the western North Atlantic is much needed, but even the completion of this work may leave a number of problems.

Among the species included here, one of the principal problems is the separation of *flexuosa*, *lingulata* and *clathrata*. While a proper determination can often be based upon macroscopic characters, especially branching, this is not at all reliable. Any one of the three may closely resemble one of the others. Dr. H. L. Blomquist (personal communication) believes that cell wall thickness (as seen in surface view) is a useful microscopic character, especially where the branching, if any, may be misleading. He points out, however, that the degree of variation of cell wall thickness with age of the plant, water temperature, salinity, and other environmental factors is not known. Taylor (1942) uses this character in his discussion of the differences between *E. flexuosa* and *E. lingulata*. The cell walls of *E. lingulata* seem to be consistently the thinnest, those of *E. clathrata* the thickest (of the three species), and those of *E. flexuosa* are intermediate.

Enteromorpha clathrata (Roth) J. Agardh

Figure 6A

Plants repeatedly branched, the branches tapering from base to apex but not ordinarily ending in a uniseriate tip. Cells in longitudinal rows, usually rectangular in shape, the chromatophore distinctly smaller than the face of the cell.

A more slender plant which has been generally referred to *E. crinita* (Roth) J. Agardh is believed by Taylor (1957, p. 64) to represent a form of *E. clathrata*. In Florida Gulf coast material, it seemed to be possible to separate these by virtue of the *E. crinita* characteristics of a chromatophore that nearly filled the face of the



FIGURE 6. A. *Enteromorpha clathrata*, habit of part of a plant. X 0.6. B. *Enteromorpha prolifera*, habit of part of a plant. X 0.6. C. *Enteromorpha flexuosa*. X 0.6. D. *Monostroma oxyspermum*, cross-section. X 266. E. *Ulva lactuca*, cross-section. X 133. F. *Cladophora fascicularis*, habit of part of a plant. X 0.6.

cell and the presence of uniseriate tips to many of the branches. Because of inadequate study of the Florida material, Taylor's treatment is followed here rather than the above-mentioned observations.

Specimens of *Enteromorpha* in good agreement with *E. plumosa* Kützinger are also included here in accordance with the treatment of Bliding (1944) who regarded *E. plumosa* as a synonym of *E. clathrata*. Plants that would be associated with the name *E. plumosa* were soft, delicately filamentous, much branched, the branches usually terminating in long uniseriate tips. The cells were in longitudinal and often transverse series, the chromatophores not covering the entire face of the cell. This form is not abundant along the Florida west coast but is widely distributed.

General Distribution.—From the Canadian Arctic to New Jersey, Europe, northwest Florida.

N. W. Florida.—Evidently continuous during winter months from Cedar Keys to Pensacola and probably west and south to Port Aransas, Texas.

References.—Taylor 1957, p. 63; Collins 1909, p. 199; Bliding 1944, p. 331; Kützinger 1843, p. 300, pl. XX, fig. 1.

Enteromorpha flexuosa (Wulfen) J. Agardh

Figure 6C

Plant unbranched (rarely branched at the base) inflated or flattened, the cells with thick walls and more or less in longitudinal rows, 10-28 microns in diameter.

General Distribution.—Bermuda, West Indies, South America, Florida; a tropical species.

N. W. Florida.—Common and continuous along the entire Florida west coast.

References.—Taylor 1928, p. 55; Collins 1909, p. 203.

Enteromorpha intestinalis (L.) Link

Similar to *E. flexuosa* in gross aspect except that the plants become larger and generally more contorted and constricted, the cell walls not so thick and not in longitudinal rows. A cold water species common during winter months only.

General Distribution.—Worldwide.

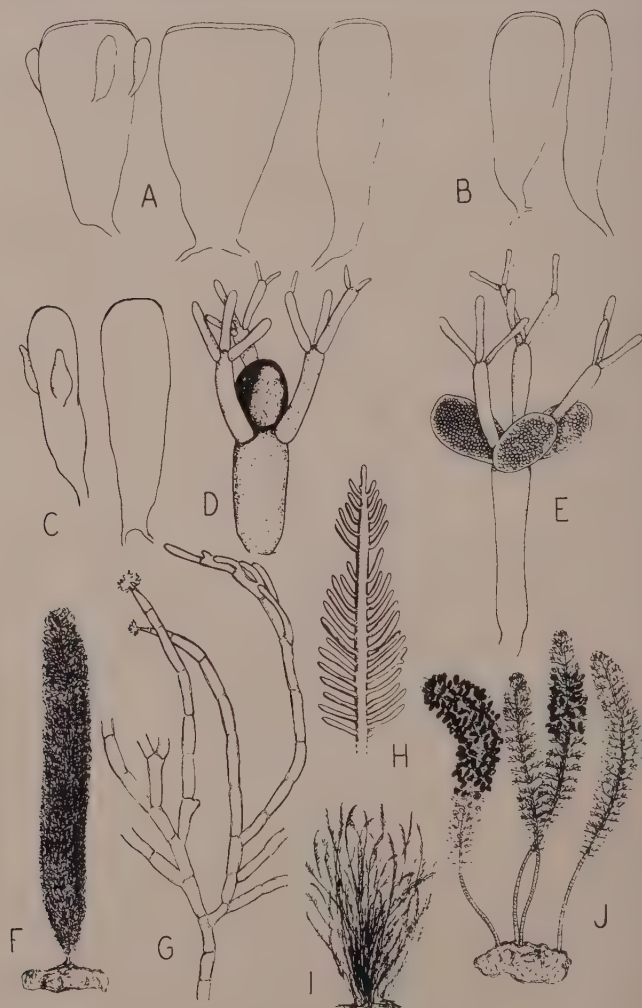


FIGURE 7. A. *Codium isthmocladum*, utricles, one with gametangia. X 40 B. *Codium taylori*, utricles. X 35. C. *Codium decorticatum*, utricles, one with gametangia. X 22.5. D. *Dasycladus vermicularis*, branchlet with a sporangium. X 12.5. E. *Batophora oerstedii*, branchlet with sporangia. X 12.5. F. *Dasycladus vermicularis*, habit of a plant. X 1.5. G. *Cladophora fuliginosa*, habit of a portion of a plant with two terminal hapterae. X 10. H-I. *Bryopsis pennata*, upper part of a branch (X 5) and habit of a plant (X 0.5). J. *Batophora oerstedii*, habit of four plants, two with sporangia. X 0.75.

N. W. Florida.—From Tampa Bay to Pensacola, more common and better developed during winter months.

References.—Collins 1909, p. 204; Taylor 1957, p. 66; 1960, p. 62.

Enteromorpha lingulata J. Agardh

Plant cylindrical, tufted or turf-forming, 3-7 cm tall, sparingly branched at the base, rarely branched in the upper parts. Branches progressively larger from the base upward from 1-5 mm; cells rectangular, in regular rows.

General Distribution.—North Carolina to Florida, the West Indies and South America; Pacific Mexico to South America.

N. W. Florida.—Probably continuous around the entire Gulf coast. A tropical species present in summer as well as winter.

References.—Børgersen 1913, p. 7; Taylor 1942, p. 13; 1960, p. 60, pl. 1, fig. 3.

Enteromorpha linza (L.) J. G. Agardh

Plants unbranched, in the form of a flat, tapering blade, lanceolate or linear-lanceolate, usually 3-5 inches tall (in Florida material) with a short, hollow stipe. In the blade portion of the plant the two layers of cells adhere as in *Ulva* except at the edges where they separate and thus form a hollow margin around the blade, a condition best seen in cross-section.

The plant is distinguished from *E. intestinalis* as the latter is hollow throughout even though it may be collapsed and flattened in broad specimens; and from *Ulva fasciata* as the cell layers of the latter are adherent throughout and the plant is typically composed of multiple lobes rather than a simple blade as *E. linza*.

From North Carolina southward *E. linza* is usually best developed in late winter and spring and absent during summer and fall.

General Distribution.—British Isles, France, Sweden, Mediterranean Sea, Ile St. Pierre to South Carolina, Brazil, Alaska to California. Collins (1909) says "Maine to West Indies," but Taylor (1928), Collins and Hervey (1917), Howe (1918, 1920) do not report this species from Bermuda, the Bahamas or Florida. It is reported from Jamaica by Taylor 1929.

N. W. Florida.—A single collection from the rock breakwater along the channel to St. Andrew Bay, Panama City. Possibly present only in the northern Gulf of Mexico.

References.—Newton 1931, p. 78 (as *Ulva linza* L.); Hamel 1931, p. 60; Taylor 1929, p. 622; LeGallo 1947, p. 302; Kylin 1949, p. 19; Feldman 1954, p. 13; Funk 1955, p. 10; Joly 1957, p. 51.

Enteromorpha prolifera (Müller) J. Agardh

Figure 6B

Plants sparingly branched throughout, the branches only occasionally branched again; cells 10-15 microns in diameter, 15-18 microns tall, in longitudinal series in the younger parts.

General Distribution.—Europe, Greenland, Canada to Florida, Bermuda, Bahamas.

N. W. Florida.—Evidently continuous along the entire Florida Gulf coast, more abundant in the northern part.

References.—Collins 1909, p. 202; Taylor 1928, p. 56; 1957, p. 65.

Enteromorpha ramulosa (Smith) Hooker

Figure 11

Plant tubular, 10-30 cm tall, to 1 mm in diameter, rather stiff, with many branches which bear short, spinelike branchlets. Cells rounded, almost completely filled by the chromatophores, in longitudinal rows only in the ultimate divisions.

General Distribution.—Europe, New Zealand, Australia, and according to Collins (1909), Massachusetts to the West Indies. The species is not reported by Taylor (1957) for New England or Florida (1928); Hoyt (1917-18) does not report it for North Carolina, nor Børgesen (1913) for the Virgin Islands. The writers have not investigated the basis for Collins' Atlantic coast range.

N. W. Florida.—Tampa Bay (Coll: Ronald Phillips), Cedar Keys, Levy County; St. Joseph Bay at Port St. Joe, Gulf County; probably continuous around the northern Gulf coast during winter months.

References.—Taylor 1954, p. 94; Collins 1909, p. 200; Newton 1931, p. 69.

Enteromorpha salina Kützinger, var. *polyclados* Kützinger

Plants entangled, slender, sparingly branched throughout or only at the base, the lower parts with short, tapering branchlets, uniseriate at the tips. Cells squarish or shorter than broad, about 16 microns wide, in longitudinal series throughout. Membrane thickened on both sides.

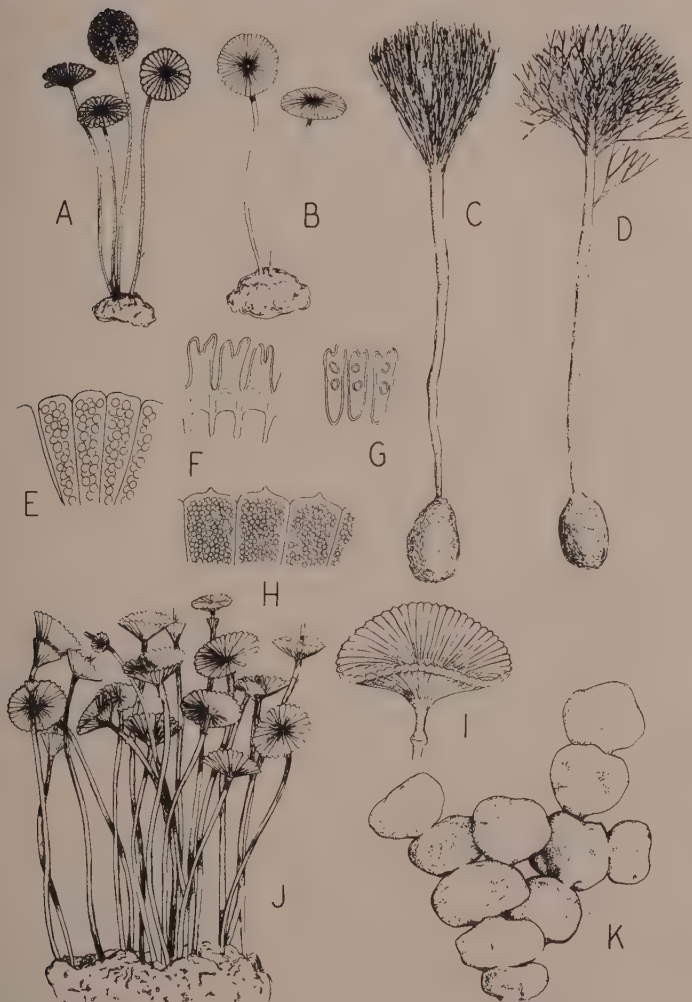


FIGURE 8. A-B. *Acicularia schenckii*, plants with nearly mature sporangia and two younger plants. X 0.6. C. *Penicillus capitatus*. X 0.6. D. *Penicillus lamourouxii*. X 0.6. E-G. *Acicularia schenckii*. E. Portion of disk showing spores (X 18). F. Corona inferior. G. Corona superior. (Both X 85). H-J. *Acetabularia crenulata*. H. Margin of disk of a young plant (X 29). I. Disk, nearly mature (X 1.4). J. Habit of a group of plants (X 0.6). K. *Halimeda discoidea*, habit of a portion of a plant. X 0.6.

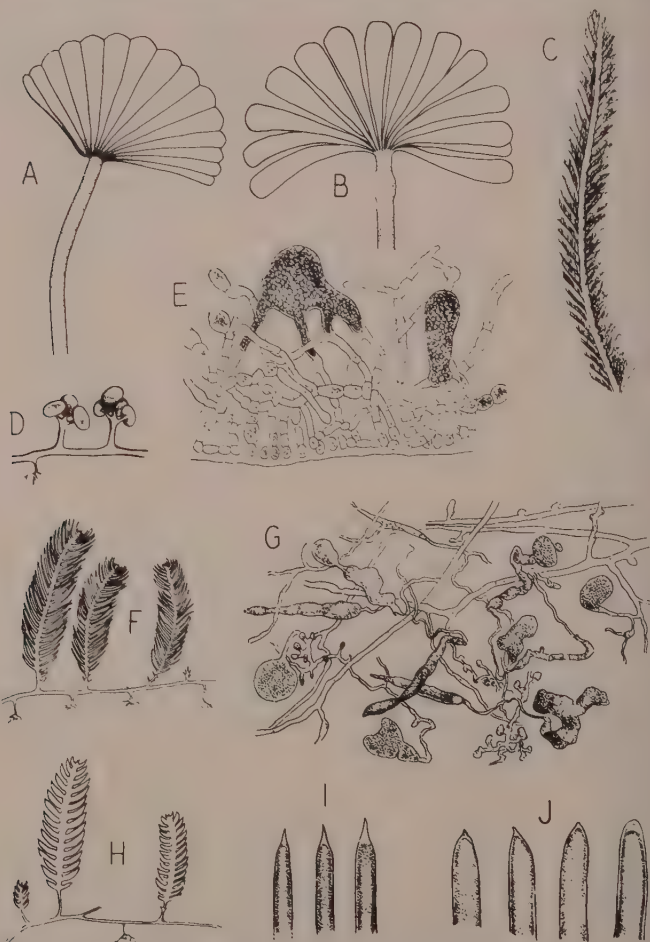


FIGURE 9. A-B. *Acetabularia farlowii*, upper portions of young plants, one with the rays adherent, the other with separated rays. X 3.2. C. *Caulerpa paspaloides*, variety *wurdemanni*, one of the whorled branches showing arrangement of pinnae. X 0.6. D. *Caulerpa peltata*, habit of a portion of a plant. X 0.6. E. *Gomontia polyrhiza*, plant mass from a decalcified shell with two sporangia. X 176. (After Newton 1931). F. *Caulerpa sertularioides*, forma *brevipes*. X 0.6. G. *Ostreobium queketti*, plant mass from a decalcified shell. X 153. (After Newton 1931). H. *Caulerpa crassifolia*, forma *typica*, habit of part of a plant. X 0.6. I. *Caulerpa paspaloides*, variety *wurdemanni*, tips of the ultimate ramuli. X 14.7. J. *Caulerpa paspaloides*, variety *minima*, tips of the ultimate ramuli. X 14.7.

General Distribution.—Europe, New England to Florida and the West Indies; Louisiana, California, Ecuador.

N. W. Florida.—Known from the mouth of the Steinhatchee River, Taylor County, to Panama City.

References.—Collins 1909, p. 202; Taylor 1928, p. 56; Howe 1920, p. 598.

Ulva fasciata Delile

Figure 17

Plant a thin sheet typically divided into long, linear segments, the blade two cells thick; the cells taller than wide in section. The blade is thicker in the center, where the cells are tallest, and thinner toward the margins, where the cells may be nearly as wide as tall. Typically a plant of rock breakwaters where there is strong surf and relatively high salinity, though it is known from protected places.

General Distribution.—Worldwide in tropical and warm waters.

N. W. Florida.—Hillsborough Bay, Tampa, and probably at more northern stations.

References.—Collins 1909, p. 216; Børgesen 1913, p. 8.

Ulva lactuca Linnaeus

Figure 4E

Plant a thin sheet two cells thick, orbicular or irregular in outline, not divided into linear segments, the sheet of about the same thickness throughout, attached at first, later drifting.

Var. *rigida* (C. Agardh) Le Jolis is distinguished by having cells which are taller than wide producing a firmer, darker green blade which is usually lanceolate at first. The chromatophores are usually across the surface face of the cells. Old plants may become perforated.

Var. *latissima* (L.) DeCandolle produces cells that are isodiametric or sometimes wider than tall, hence the blade is thinner. The chromatophores are usually against the vertical walls of the cells, hence the blade is usually lighter in color. This variety is more characteristic of salt marshes or bays with muddy bottoms.

General Distribution.—Worldwide.

N. W. Florida.—Both varieties are continuous along the entire Gulf coast, reaching their peak of development in the spring.

References.—Hoyt 1917-18, p. 421; Collins 1909, p. 214.

Monostroma oxyspermum (Kützinger) Doty

Figure 6D

Plant a thin sheet one cell (20-25 microns) thick, broadly lanceolate to orbicular, the cells irregular in arrangement, polygonal or rounded, 8-17 microns in diameter, round to oval in vertical section. Until recently plants of this species from Florida have been referred to *M. latissimum* (Kützinger) Wittrock. Taylor (1957) discusses this problem.

General Distribution.—Maine to Florida; Alaska to Washington; Europe, Africa, New Zealand.

N. W. Florida.—Probably continuous along the entire Florida Gulf coast, especially near the mouths of streams.

References.—Collins 1909, p. 211; Taylor 1957, p. 72; 1960, p. 64.

Order CLADOPHORALES

Family CLADOPHORACEAE

Chaetomorpha brachygona Harvey

Plant an uniseriate, unbranched filament of multinucleate cells 80-175 microns in diameter, about 1 diameter long, shorter just after division. In tide pools or shallow water in sheltered places, in salt marshes, loose and entangled. A tropical species.

General Distribution.—Bermuda, North Carolina to Florida, the West Indies, Mexico, northern South America.

N. W. Florida.—Evidently continuous along the Florida west coast.

References.—Collins 1909, p. 325; Hoyt 1917-18, p. 426; Howe 1920, p. 599.

Chaetomorpha aerea (Dillwyn) Kützinger

Figure 5F

Plants growing in dense clumps, each filament attached at the base, 125-175 microns in diameter, sometimes to 300 or more. Base of filament usually somewhat more slender than the upper parts, the basal cell thick-walled, about 4 times as long as its greatest diameter, producing rhizoids. Cells as long as broad to twice their diameter, the fertile cells swollen to nearly spherical.

General Distribution.—Prince Edward Island to the West Indies, California, Britain, Southern Saghalien Island (USSR); of worldwide distribution.



FIGURE 10. A-B. *Caulerpa paspaloides*, A. Variety *minima*, a penultimate branch showing arrangement of the ramuli. X 8.8. B. Variety *typica*, a penultimate branch showing arrangement of the ramuli. X 5.9. C. *Caulerpa prolifera* X 0.3. D. *Caulerpa crassifolia*, forma *mexicana*, an erect branch. X 0.3. E. *Caulerpa paspaloides*, variety *minima*, an erect branch showing arrangement of the penultimate branches. X 2.9. F. *Caulerpa racemosa*, variety *clavifera*. X 1.8. G. *Cladophora fuliginosa*, part of a branch. X 11.8. (After Taylor 1928).

N. W. Florida.—One clump from limestone rocks in shallow water off Taylor County, June 4, 1954, collected by John Morrill and F. C. W. Olson.

References.—Collins 1909, p. 324; Newton 1931, p. 92; Taylor 1957, p. 79; 1960, p. 72.

Chaetomorpha linum (Müller) Kützing

Figure 5G

Similar to *C. brachygona* except that the filaments are 180-300 microns in diameter, the cells usually a little longer than broad and thick-walled.

General Distribution.—Canada to Florida and the West Indies, Panama, Ecuador, Mediterranean Sea.

N. W. Florida.—Alligator Harbor, Franklin County.

References.—Collins 1909, p. 325; Taylor 1928, p. 60; 1960, p. 71, pl. 2, fig. 8.

Genus *Cladophora* Kützing, 1843

Plants filamentous, monosiphonous, much-branched, the cells multinucleate.

Cladophora brachyclona Montagne

Figure 5C

Plants with main axes to 250 microns diameter, the main branches di-polychotomous, the cells 4-6 diameters long. Branching more dense in the upper parts, the cells shorter and with constricted nodes, the ultimate branches short, tapering, often of a single cell, alternate, opposite or secund, 50-75 microns in diameter, the cells ellipsoid, 1-2 diameters long.

General Distribution.—Mediterranean Sea, Bermuda.

N. W. Florida.—On limestone rocks near the main pier at St. Theresa, Franklin County, in 3 feet of water. Newly reported for Florida and the U. S.

References.—Collins 1909, p. 341; Taylor 1960, p. 87.

Cladophora delicatula Montagne

Plants loosely branched, soft, delicate, to a height of 3 or 4 inches, the main filaments 40-60 microns in diameter, the cells 3-6 diameters long; ultimate ramuli often in short, secund series in larger plants, the

cells 20-30 microns in diameter, 1-3 diameters long, sometimes slightly constricted at the nodes.

Florida material referred to this species was mostly less than one inch tall and epiphytic.

General Distribution.—Florida and the West Indies.

N. W. Florida.—Breakwater at the entrance of St. Andrew Bay, Panama City; buoy 26 off Franklin County, and other stations. Probably generally distributed along the entire Gulf coast but easily overlooked.

References.—Collins 1909, p. 337; Taylor 1928, p. 61; Collins and Hervey 1917.

Cladophora fascicularis (Mertens) Kützinger

Figure 6F

Plants to 18 inches tall, the main axes 200-360 microns in diameter, cells 2-5 diameters long. Branching alternate, the penultimate branches producing branchlets in fasciculate groups, 1.5-3 mm long with cells 70-120 microns in diameter, 1-3.5 diameters long. A species typical of exposed places as on breakwaters in the surf, also sometimes free-floating in protected places where it may form an entangled mass.

General Distribution.—North Carolina to Florida, West Indies, Bermuda to Uruguay.

N. W. Florida.—Evidently continuous along the Florida west coast. Typical large plants are most frequently encountered on rocks in the surf where the water is usually clear and of high salinity, especially between Tarpon Springs and Tampa Bay. In 25-30 feet of water around buoy 26, about 9 miles S. E. of Alligator Point, Franklin County, a growth form occurs on shells and coralline algae which differs in having slender ultimate ramuli (18-20 microns diameter) with very sharp tips. The plants are small (2-4 inches), pale green, silky, usually with bare main axes that exceed 200 microns in diameter. Dr. H. K. Phinney kindly examined this material and pointed out that it falls within the present scope of *C. fascicularis*, but that this disposition does not seem very satisfactory and that it probably should have at least varietal rank.

References.—Collins 1909, p. 345; Taylor 1928, p. 62; 1960, p. 91, pl. 3, fig. 3.



FIGURE 11. *Enteromorpha ramulosa*, photograph of an herbarium specimen. This material was collected from intertidal rocks at the Tampa end of Gandy bridge, December 30, 1957, by Ronald Phillips.

Cladophora fuliginosa Kützing

Figure 10G

Plants with main axes usually 150-160 (to 380) microns in diameter, the cells 5-10 diameters long. Filaments firm and stiff, dichotomous or alternately branched and bearing short, blunt branchlets in second series. Plants forming brownish-green tufts, usually in shallow water. Evidently always parasitized by an endophytic fungus, *Blodgettia borneti* Wright.

General Distribution.—Florida, West Indies, Cuba, British Honduras.

N. W. Florida.—Alligator Point, Franklin County (Taylor 1954).

References.—Collins 1909, p. 348; Børgesen 1913, p. 22.

Cladophora glaucescens (Griffiths) Harvey

Plants 3-12 inches or more in height, in loose tufts, much branched, the branches typically terminating in long, alternate or sometimes secund ramuli. Main branches 40-60 microns in diameter, the ramuli 20-30 with cells usually 3-4 diameters long or longer. The plants are typically pale green, rather glassy, and relatively rigid for the slenderness of the filaments and in comparison to *C. delicatula*.

General Distribution.—Labrador to Florida.

N.W. Florida.—A single collection formed a pale green turf about 1 cm tall on a piece of nylon rope entangled in the rocks of the break-water along the entrance to St. Andrew Bay, Panama City.

References.—Collins 1909, p. 336; Taylor 1928, p. 63; 1960, p. 86.

Cladophora gracilis (Griffiths) Kützing

Figure 5 A-B

Plants with main axes usually less than 150 microns in diameter, irregularly bent, branching at the angles, the upper parts bearing secund series of long, tapering, acute branchlets 40-60 microns in diameter, the cells 3-5 diameters long. Typical of salt marshes and protected places, brackish water, and the intertidal zone where shaded.

General Distribution.—Europe, Greenland to Florida, Texas, Pacific Mexico.

N.W. Florida.—One of the most common species in salt marshes, often among *Spartina* and intertidal; sometimes in deeper water.

References.—Collins 1909, p. 342; Taylor 1928, p. 63; 1960, p. 90.

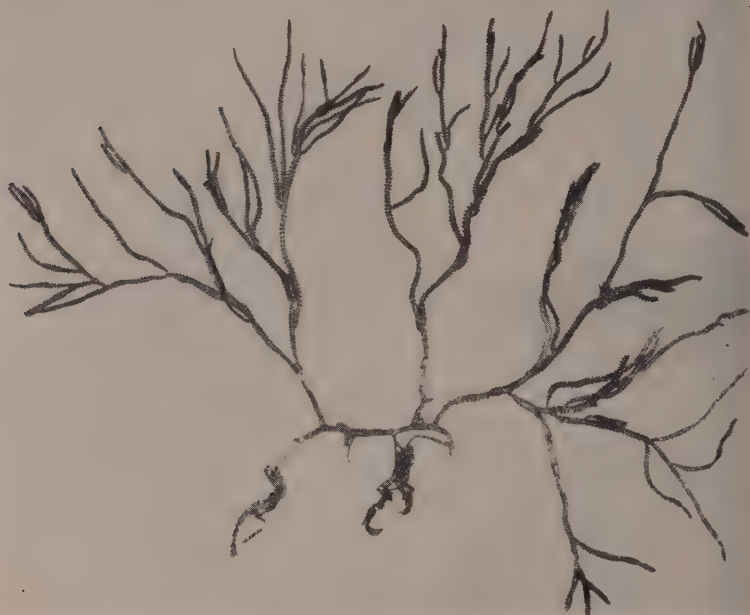


FIGURE 12. *Caulerpa cupressoides*, variety *flabellata*. Photograph of an herbarium specimen. This material on sea grass flats just south of Pepperfish Keys (off Dixie County), June 8, 1954, by John Morrill and F. C. W. Olson.

Rhizoclonium kochianum Kützing

Figure 5H

Plant of unbranched filaments, 10-14 microns in diameter, the cells 1-7 diameters long, with net-shaped chromatophore and several pyrenoids.

General Distribution.—New England to Florida, West Indies, Pacific Mexico.

N.W. Florida.—From limestone rocks in 8-10 feet of water about 5 miles E.S.E. of St. Marks light, Wakulla County.

References.—Collins 1909, p. 329; Børgesen 1913, p. 20.

Rhizoclonium kochianum var. *kerner*i (Stockmayer) Hamel

Figure 5K

Similar to *R. kochianum* except that the cells are 1-2 diameters long.

General Distribution.—Europe, West Indies.

N.W. Florida.—Tampa Bay at the west end of Gandy bridge.

References.—Collins 1909, p. 249; Børgesen 1913, p. 19. (both as *R. kerner*i Stockmayer).

Rhizoclonium riparium (Roth) Harvey

Figure 5J

Similar to *R. kerner*i except that the filaments are usually 20-25 microns in diameter (15-30 or more), 1-2 diameters long, and (rarely, in Florida material) may produce short, rhizoidal branches. A plant of salt marshes and brackish water.

General Distribution.—Worldwide.

N.W. Florida.—Continuous from Tampa Bay around the Gulf coast to Texas.

References.—Collins 1909, p. 327; Howe 1920, p. 600.

Order SIPHONALES

Family DERBESACEAE

Derbesia vaucheriaeformis (Harvey) J. Agardh

Figure 5 D-E

Plants forming dense tufts, the filaments dichotomously branched, 1-5 cm tall, 35-50 microns in diameter, soft and lubricous, the apices obtuse. Sporangia borne on the lower parts of the plants, apparently replacing a branch, ovate to pyriform, 75-115 by 130 to 180 microns (in Florida material), containing about 64 spores (?) 16-18 microns in diameter, ovoid; sporangia with a short stalk cell about 15 microns in diameter and two diameters long.

Collins' (1909) and Harvey's (1858) descriptions of this plant indicate about 16 spores in a mature sporangium. The large number present in the Florida material may indicate them to be gametangia rather than sporangia. Gametangia have apparently not been observed previously.

General Distribution.—Southern Massachusetts, North Carolina, Bermuda, Bahamas, Florida.

N.W. Florida.—In rock-concavity tide pool, rock breakwater along the west side of the channel of St. Andrew Bay, Panama City mixed with *Polysiphonia denudata* (Dillwyn) Kützling, *Ceramium byssoideum* Harvey, *Bryopsis pennata* and *Enteromorpha flexuosa*.

References.—Harvey 1858, p. 30 (as *Chlorodesmis* ? *vaucheriaeformis*); Farlow 1881, p. 60 (as *Derbesia tenuissima*); Collins and Hervey 1917, p. 62; Howe 1920, p. 610; Williams 1948, p. 685; Pearse and Williams 1951, p. 152; Collins 1909, p. 406.

Family BRYOPSIDACEAE
Bryopsis pennata Lamouroux
Figure 7 H-I

Plant coenocytic with a branched stipe from a rhizoidal base, 2-5 cm tall, the upper branches bearing distichous, determinate branchlets of uniform length, their bases constricted.

General Distribution.—North Carolina to Florida, West Indies to Mexico.

N.W. Florida.—Breakwater at Mullet Key, Tampa Bay; groins at Clearwater Beach; rocks at Pass-a-Grille near St. Petersburg; St. Andrew Bay, Panama City. Probably continuous.

References.—Vickers 1908, p. 52; Taylor 1928, p. 93; Lamouroux 1809a, p. 134, pl. VII, figs. 1a + b.

Family CAULERPACEAE
Genus *Caulerpa* Lamouroux, 1809

Plants coenocytic with creeping stolon which gives rise to upright, determinate branches and to descending rhizoids, the erect branches ranging from simple filaments to elaborately branched structures. The rhizoids, stolon, and erect branches or branchlets suggest roots, stems, and leaves of the higher plants. Trabeculae extend from wall to wall within the coenocyte. Zoospores produced (rather rarely) in sporangia formed locally in the upper parts by a transverse wall.

Reference.—Weber van Bosse, 1898.

Caulerpa ashmeadii Harvey
Figure 16

Erect branches distichous, mostly 4-13 cm tall, producing two rows of cylindrical or slender, clavate branchlets, 10-18 mm long, with blunt or rounded tips. Much variation of erect branches occurs includ-

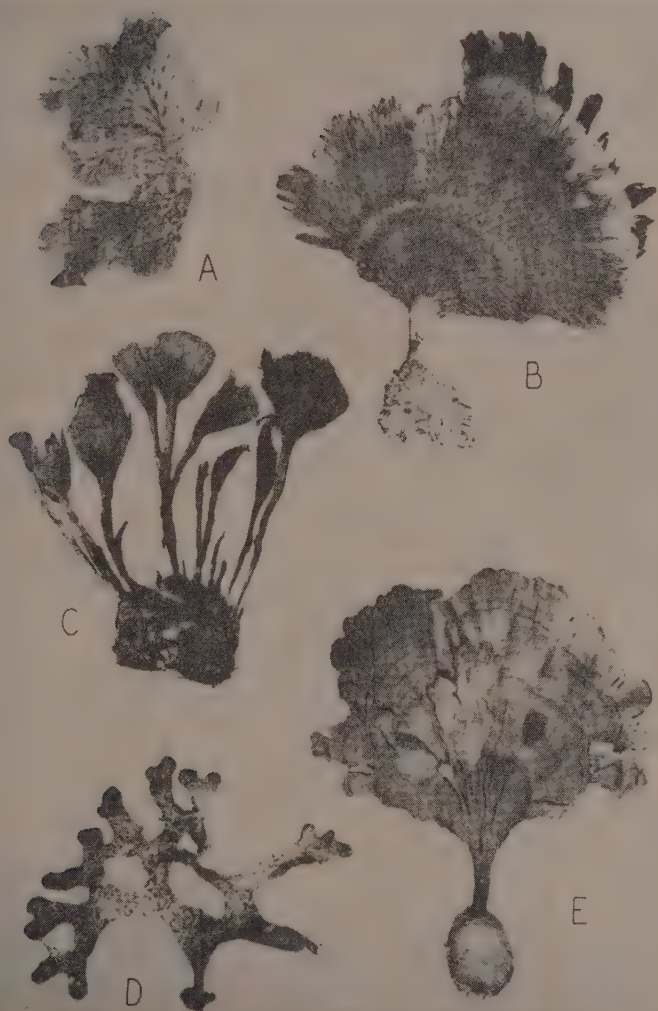


FIGURE 13. A. *Anadyomene stellata*, photograph of an herbarium specimen. X 0.6. B. *Udotea conglutinata*, photograph of an herbarium specimen. X 0.3. C. *Penicullus capitatus*, photograph of a cluster of plants. X 0.3. D. *Codium taylori*, photograph of an herbarium specimen. X 0.6. E. *Udotea flabellum*, photograph of a fresh specimen. X 0.3.

ing some with very few branchlets, sometimes the branchlets are secund, occasionally there is no branch. Taylor (1928) found a distinct spine at the apex of the branchlets on specimens from the Dry Tortugas, but all N.W. Florida material had blunt tips, which seems to be the typical condition.

General Distribution.—Florida and the Virgin Islands.

N.W. Florida.—Among *Thalassia* in shallow water where it is usually quite inconspicuous because of the taller associate; continuous at least from Tampa Bay to Alligator Harbor, Franklin County.

References.—Collins 1909, p. 414; Børgesen 1913, p. 135.

Caulerpa crassifolia (C. Agardh) J. Agardh

Figure 9H; Figure 10D

Erect branches pinnate, mostly 2-10 cm tall, the branchlets flattened, often curved, tapering to a point.

Forma *typica* (Weber) Børgesen has erect branches to 6.5 cm tall and about 1 cm wide with branchlets about 1.5 mm wide, not much tapered at the base, somewhat falcate to nearly straight.

Forma *mexicana* (Sonder) J. Agardh has erect branches to 7 cm tall and about 17 mm wide, the branchlets 2.5 mm wide, much narrowed at the base and distinctly falcate.

General Distribution.—Worldwide in tropical seas.

N.W. Florida.—On mangrove roots, rocks or muddy sand; forma *typica* continuous from Tampa Bay to Alligator Harbor, Franklin County; forma *mexicana* evidently only in the southern part of this range.

References.—Børgesen 1913, p. 130; Vickers 1908, plate 40 (f. *mexicana*).

Caulerpa cupressoides (West) C. Agardh

Figure 12

Erect branches dichotomously branched bearing short branchlets in two, three or many ranks, conical, flattened to cylindrical in shape and always sharply pointed. The species is highly variable as indicated by the seven varieties and six forms listed by Collins (1909). Taylor (1928) lists all the varieties and two forms for Florida.

Variety *flabellata* Børgesen has branchlets 1-3 times as long as the midrib. All specimens from Tampa Bay northwards seem to fit this variety.

General Distribution.—Worldwide in tropical seas.

N.W. Florida.—Tampa Bay to Pepperfish Keys off Dixie County; probably farther north and west.

References.—Børgesen 1913, pp. 135-147, fig. 113; Taylor 1928, p. 96; Collins 1909, p. 416.

Caulerpa paspaloides (Bory) Greville

Figure 9C,I-J; Figure 10A-B,E; Figure 14

Plants bearing palmately or dichotomously branched erect branches, the pedicel bare up to the point of branching. Branches covered with branchlets in 3 or 4 alternating ranks, these in turn with 1 or 2 ranks of pinnules along the upper side, the pinnules usually sharp-pointed. This species is extremely variable, ranging in height from 1-15 cm. Two varieties representing extremes are known from N.W. Florida.

Variety *wurdeimanni* Weber has pedicels about 8 cm high with branches to 10 cm long, the branchlets biseriate, subopposite, or scattered with two ranks of unilateral, simple pinnules.

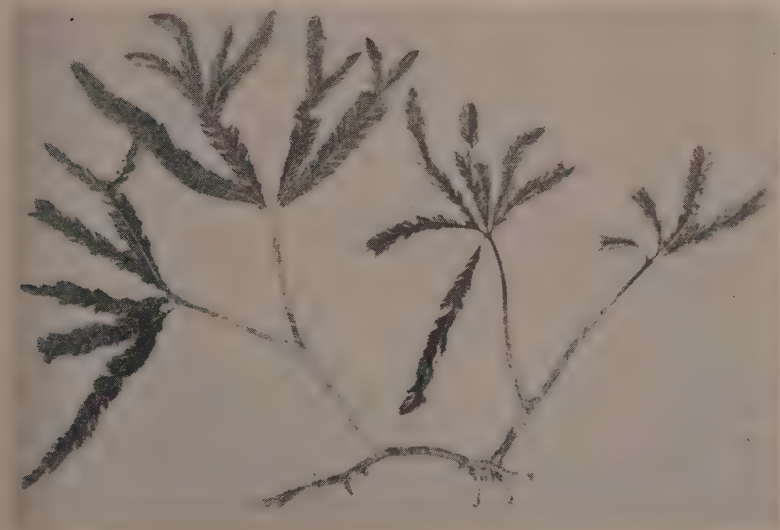


FIGURE 14. *Caulerpa paspaloides*, variety *wurdeimanni*, photograph of an herbarium specimen. X 0.34. Collected at a depth of 10 feet about 5 miles E.S.E. of St. Mark's Light (off Wakulla County), May 7, 1955.

Variety *minima* n. var. is about 1 cm tall, forming an involved or entangled mass on rocks or sponges, the branchlets in 2 or 3 ranks, 2 of which are approximate, the other more or less opposite them. Pinules simple and secund on the upper side of the branchlet with sometimes a remnant of a second row in evidence at the base of the branchlets.

General Distribution.—Florida, West Indies, Caribbean Sea, Gulf of Mexico.

N.W. Florida.—Both varieties seem to be continuous from Cedar Keys to the area of scattered limestone rocks on the bottom about 5 miles E.S.E. of St. Marks light, Wakulla County; Var. *wurdeimanni* among *Thalassia*.

References.—Collins 1909, p. 418; Taylor 1928, p. 99.

Caulerpa peltata (Turner) Lamouroux
Figure 9D

Erect branches 5-15 mm tall, simple or branched, the branchlets peltate, 3-8 mm in diameter, on short pedicels.

General Distribution.—Florida and the West Indies.

N.W. Florida.—On rocks in shallow water, St. Petersburg Beach.

References.—Taylor 1928, p. 100; Collins 1909, p. 421; Lamouroux 1809, p. 145, pl. VII, figs. 2a and b.

Caulerpa prolifera (Forsskal) J. Agardh
Figure 10C

Upright branches in the form of flat blades, linear to lanceolate, sometimes proliferous, 4-15 cm tall, 7-20 mm wide or more.

General Distribution.—North Carolina to Florida, West Indies, Gulf of Mexico, the Mediterranean Sea.

N.W. Florida.—Continuous from Tampa Bay to Alligator Harbor, Franklin County. Much of the more northern material resembles forma *zosterifolia* Børgesen except that the blades are not often interrupted nor abundantly proliferous. Forma *obovata* is more common in the southern part of this range, sometimes occurring on large rocks exposed to surf. The obovate-oblong blades may exceed 15 cm in height.

References.—Collins 1909, p. 413; Taylor 1928, p. 100; Lamouroux 1809, p. 142.

Caulerpa racemosa (Forsskal) J. Agardh

Figure 10F

Erect branches usually much-branched and with the ends swollen to spheres, sometimes somewhat flattened or the end merely swollen to form a clavate branchlet. A highly variable species with 7 varieties reported for Florida, (Taylor 1928).

Variety *clavifera* (Turner) Weber. Erect axes 1-3 cm tall, pedicels 0.5 to 1 mm long rather gradually expanded to a rounded end.

General Distribution.—Worldwide in tropical seas.

N.W. Florida.—Variety *clavifera* was collected drifting at Clearwater Beach, Pinellas County.

References.—Vickers 1908, plate 45; Collins 1909, p. 419-421.

Caulerpa sertularioides (Gmelin) Howe

Figure 9F

Erect branches with two rows of distichous branchlets producing a flat blade, the branchlets sometimes in 3 or more ranks and surrounding the erect axis, always with pointed tips.

Forma *brevipes* (J. Agardh) Svedelius. Erect axis rarely forked, the blade sessile or nearly so.

General Distribution.—Worldwide in tropical seas.

N.W. Florida.—Pass-a-Grille, Pinellas County and in Alligator Harbor, Franklin County. Probably more or less continuous between these two distant stations.

References.—Vickers 1908, plate 42; Børgesen 1913, p. 133.

Family CODIACEAE

Avrainvillea levis Howe

Plants composed of a stalk 3-5 cm long, 5-6 mm in diameter with a flat blade at the top, 4-7 cm tall and about 5-9 cm wide, dull green in color, the blade soft and somewhat spongy in texture and zonate, broadly rounded to reniform in shape often with a slightly cordate base. Structurally, the plant is composed of coenocytic filaments that are dichotomously branched, constricted above the forks and without specialized cortical filaments in the blade (in contrast to the genus *Udotea*). Surface filaments of the blade rather closely interwoven to form an incipient cortical layer, not moniliform-constricted or only



FIGURE 15. *Halimeda incrassata*, photograph of an herbarium specimen. X 0.3. This plant was collected from a depth of 8 feet about 5 miles E.S.E. of St. Mark's Light (off Wakulla County), May 26, 1952.

slightly so in the ultimate divisions, 10-24 microns in diameter; axial filaments coarser, 20-35 microns in diameter, not moniliform constricted. Plants not calcified.

This species is known for Florida by a single collection of a few good specimens obtained by Dr. W. R. Taylor by dredging in 91.5 meters depth in Southwest Channel, Dry Tortugas. The extension of its range 500 miles northward and into shallow water seems remarkable, but the abundant material obtained agrees well with Howe's (1907) description.

General Distribution.—Florida, Bahamas, West Indies.

N.W. Florida.—From one locality at St. Teresa, Franklin County, in 3-6 feet of water in a rather sparse stand of turtle grass (*Thalassia testudinum*) interrupted by occasional limestone rocks 200-300 feet from the beach. Hundreds, perhaps thousands, of plants were present at this station in the summer of 1959. Since the area had been rather thoroughly collected during the years 1951-54 without obtaining this species, it is possible that it has only recently invaded the area.

References.—Howe 1907; Collins 1909, p. 390; Taylor 1928, p. 77; 1960, p. 162.

Genus *Codium* Stackhouse, 1795

Plants structurally composed of branching, coenocytic filaments in the form of axial strands which produce a radial corticating layer composed of much-expanded utricles with blunt ends. These are so closely associated laterally as to form an erect, branched plant of spongy or rope-like texture, the branches 3-10 mm or more in diameter, usually dichotomous. Utricles producing 2-4 gametangia laterally which are ovate or cone-shaped.

Codium decorticatedum (Woodward) Howe

Figure 7C

Plants 6 inches to several feet tall, dichotomous, the branches typically flattened below the dichotomies. Utricles 300-570 microns in diameter, the end walls not thickened. Dioecious.

General Distribution.—North Carolina to Florida, Bermuda, West Indies, South America, Europe, Africa.

N.W. Florida.—Common in Tampa Bay and vicinity; abundant on rocks in 8-10 feet of water 5-7 miles E.S.E. of St. Marks light, Wakulla County; probably continuous between these stations though evidently not collected.

References.—Williams 1948; Hoyt 1917-18, p. 433; Silva 1960, p. 516.

Codium isthmocladum Vickers

Figure 7A

Similar to *C. decorticatedum* but lacking the flattening below the dichotomies and with utricles 120-460 microns in diameter or more,

usually 250-300. End walls of utricles thickened, 18-56 microns. Dioecious.

General Distribution.—Bermuda, Florida, West Indies (type from Barbados).

N.W. Florida.—Common from Cedar Keys to Franklin County. Growing attached on limestone rocks at St. Teresa, Franklin County; on rocks in 8-10 feet of water 5-7 miles E.S.E. of St. Marks light, Wakulla County and at Cedar Keys. Probably continuous along the entire Florida Gulf coast.

References.—Vickers 1908, plate 28; Børgesen 1913, p. 115; Taylor 1928, p. 79; Silva 1960, p. 503.

Codium taylori Silva
Figure 7B; Figure 13D

Plant generally cylindrical, though distinctly flattened below the dichotomies, dark green, stiff, densely branched. Utricles broadly spindle-shaped to clavate or cylindrical, the ends broadly rounded, 125-300 microns in diameter, 2-5 diameters long.

General Distribution.—Bermuda, West Indies, Florida.

N.W. Florida.—On rocks, Mullet Key, Tampa Bay; rocks at the end of the peninsula, Pass-a-Grille, Pinellas County, and at Cedar Keys.

References.—Taylor 1928 (as *C. pilgeri*), p. 30; Silva 1960, p. 510.

Codium repens Crouan (?)

Plant small, of slender terete branches mostly 2-3 mm in diameter, light green, soft, upper parts of the branches densely tomentose. Utricles 100-340 microns in diameter, mostly 150-250, 1.5-2 times as long as wide, cylindrical to clavate, the ends rounded or truncate in the larger utricles, the end walls only slightly thickened (3-5 microns). Hairs 15-25 microns in diameter, much constricted at point of attachment (to about half the diameter), about 1 mm long, finally deciduous, leaving a conspicuous scar at the upper edge of the utricles. Gametangia not seen.

Dr. P. C. Silva (personal communication) tentatively places material described above in this species. The description given above applies to the material obtained in connection with the present study and not to typical *C. repens* which is characterized by a creeping habit and short, special branches that attach it at intervals to the substratum.

General Distribution.—Challenger Bank, Bermuda (P. C. Silva); Florida, Campeche Bank, Gulf of Mexico (Humm 1952, a fragment not determined at that time).

N.W. Florida.—On limestone rocks in shallow water off Yankeetown; rocks in 8-10 feet of water about 5-7 miles E.S.E. of St. Marks light, Wakulla County; in 25-30 feet of water near buoy 26, about 10 miles S.E. of Alligator Harbor.

References.—Collins 1909, p. 388; Vickers 1908, pl. XXIX; Taylor 1928, p. 80; Silva 1960, p. 514, pl. 113, 122, 123.

Halimeda discoidea Decaisne

Figure 8K

Plant erect, usually 6-15 cm tall, branched, growing in sandy bottom and anchored by a dense cluster of rhizoids at the base; composed of flattened, smooth, orbicular or suborbicular segments 1-3 cm in diameter, lightly calcified, united at the edges in one plane, their margins entire. Structure fundamentally filamentous, coenocytic, the central filaments producing expanded utricles at the periphery which are laterally appressed and polyhedral when viewed from above, mostly 40-60 microns in diameter (to 85).

General Distribution.—Worldwide in warm waters.

N.W. Florida.—Dredged near Honeymoon Island, Dunedin, Pinellas County and near buoy 26 in 25-30 feet of water 5-7 miles E.S.E. of St. Marks light, Wakulla County; probably continuous from Tampa Bay to Pensacola.

References.—Collins 1909, p. 400; Børgesen 1913, p. 107; Taylor 1928, p. 82; Hillis 1960, p. 352.

Halimeda incrassata (Ellis) Lamouroux

Figure 15

Differing from *H. discoidea* in that the lower part of the plant forms an extensive stalk, branched and composed of segments more or less terete and fused. Above the stalk the segments are triangular to ovate or even cylindrical, 4-10 mm in diameter, sometimes 3-lobed, often entire, usually with prominent ribs or ridges. Utricles 42-84 microns in diameter. Plants 15-25 cm tall.

General Distribution.—Bermuda, Florida, West Indies.

N.W. Florida.—Apparently continuous from Tampa Bay to Franklin



FIGURE 16. *Caulerpa ashmeadii*, photograph of an herbarium specimen. This plant was collected at a depth of 10 feet about 5 miles E.S.E. of St. Mark's Light (off Wakulla County); May 7, 1955. X 0.3.

County. Abundant and well-developed in *Thalassia* 5-7 miles E.S.E. of St. Marks light, Wakulla County, the upper branches of these plants are more slender and less calcified than plants from southern Florida. Also around limestone rocks in 3-5 feet of water at St. Teresa, Franklin County. Probably to Pensacola. These plants agree with forma *tripartita* (Barton) Collins.

References.—Taylor 1928, p. 84; Howe 1907, p. 501 (as *H. tridens*); Hillis 1960, p. 365.

Penicillus capitatus Lamarck

Figure 8C; Figure 13C

Plants mostly 7-15 cm tall, composed of an erect stipe bearing a head of slender, dichotomously branched, lightly calcified filaments which are densely fasciculate. Filaments of the head 100-200 microns in diameter, the stipe penetrating to the center of the head.

General Distribution.—Bermuda, West Indies, Florida, Caribbean Sea. *N.W. Florida*.—From Tampa Bay to the rock islands off Taylor County.

References.—Taylor 1928, p. 86; Collins 1909, p. 392.

Penicillus lamourouxii Decaisne

Figure 8D

Differing from *P. capitatus* in that the filaments of the head are 350-500 microns in diameter.

General Distribution.—West Indies, Caribbean Sea, Florida.

N.W. Florida.—Continuous from Tampa Bay to the rocky areas in 8-10 feet of water 5-7 miles E.S.E. of St. Marks light, Wakulla County and probably to Pensacola. This species seems to extend farther north in the Gulf than *P. capitatus*.

References.—Taylor 1928, p. 86; Collins 1909, p. 392.

Udotea conglutinata (Ellis and Solander) Lamouroux

Figure 13B

Plants mostly 10-15 cm tall, composed of an erect stipe bearing a flat blade that is orbicular or fan-shaped. Structurally composed of dichotomous filaments which in the blade are 25-45 microns in diameter (to 60), lightly calcified, without corticating branches or projections; the stalk with a dense cortex of widely branched surface filaments, the terminal segments very slender, tapering, thickened at the end.

General Distribution.—North Carolina, Bermuda, Florida, West Indies, Caribbean Sea.

N.W. Florida.—Same distribution as *Penicillus lamourouxii*. This species seems to extend farther north in the Gulf than *U. flabellum*.

References.—Taylor 1928, p. 89; Collins 1909, p. 395.

Udotea flabellum (Ellis and Solander) Howe

Figure 13E

Differing from *U. conglutinata* in that the blade is firm and smooth, not obviously filamentous. The filaments of the blade produce a cortex of densely branched surface filaments with truncate and thickened ends. The blade is often proliferous from the face or margin.

General Distribution.—North Carolina, Bermuda, West Indies, Caribbean Sea.

N.W. Florida.—Tampa Bay to the rock islands off Taylor County; showing the same distribution as *Penicillus capitatus*.

References.—Taylor 1928, p. 90; Collins 1909, p. 395.

Family VALONIACEAE

Anadyomene stellata (Wulfen) C. Agardh

Figure 4J; Figure 13A

Plant with a rhizoidal base and a crisp cluster of flat blades, 3-6 cm in height, the blades ovate to reniform in shape, mostly one cell layer in thickness. Throughout the blades there are fan-shaped, branching groups of cells which form pseudo-veins. The area between veins is filled with oval to elongate cells with their long axes oriented in different directions.

General Distribution.—Bermuda, Florida, West Indies and Caribbean Sea to South America.

N.W. Florida.—Continuous from Tampa Bay to the limestone rocks in 8-10 feet of water 5-7 miles E.S.E. of St. Marks light, Wakulla County and probably to Pensacola.

References.—Taylor 1928, p. 70; Collins 1909, p. 365.

Cladophoropsis membranacea (C. Agardh) Børgesen

Figure 4K

Filamentous, monosiphonous, much-branched, forming a loose cushion or rather rigid, dense tufts, without a definite main axis. Main

filaments 170-270 microns in diameter, the branches 100-150. Differing from *Cladophora* in the frequent absence of crosswalls at the base of ultimate branches where the lowest crosswall may be considerably above the axil. Plants attached or drifting.

General Distribution.—Florida, Bermuda, West Indies, Caribbean Sea, Gulf of Mexico.

N.W. Florida.—The attached form of the species is continuous from the Florida Keys to Alligator Harbor, and probably to Pensacola.

References.—Børgesen 1913, p. 42-48; Taylor 1928, p. 65; 1960, p. 117, pl. 2, fig. 1, pl. 3, fig. 2.

Family PHYLLOSIPHONACEAE

Ostreobium quekettii Bornet and Flahault

Figure 3F; Figure 9G

Plants of slender, branched filaments which penetrate shells and the calcareous tests of invertebrate animals, irregular in diameter and with occasional inflated portions; the filaments mostly 4-10 microns in diameter; tapering to 2 microns diameter at the tips of the branches. Inflated portions to 40 microns diameter.

General Distribution.—Atlantic coast of North America from the Arctic to the tropics (?), probably, but not yet recorded, along the southeastern Atlantic coast; British Isles, Scandinavian Peninsula, France.

N.W. Florida.—In the test of a calcareous bryozoan, buoy 26 about 10 miles S.E. of Alligator Point, Franklin County. Probably common and continuous along the Gulf coast, but seen only when calcareous material is decalcified.

References.—Taylor 1957, p. 95; Newton 1931, p. 100; Kylin 1949, p. 69.

Order DASYCLADALES

Family DASYCLADACEAE

Acetabularia crenulata Lamouroux

Figure 8 H-J

Plant composed of a slender, calcified stipe to 7 cm high bearing a concave disk at the top which is 6-18 mm in diameter and made up of 30-80 moderately calcified segments or rays. Some plants produce two or more disks, one above the other. On the upper concave surface of

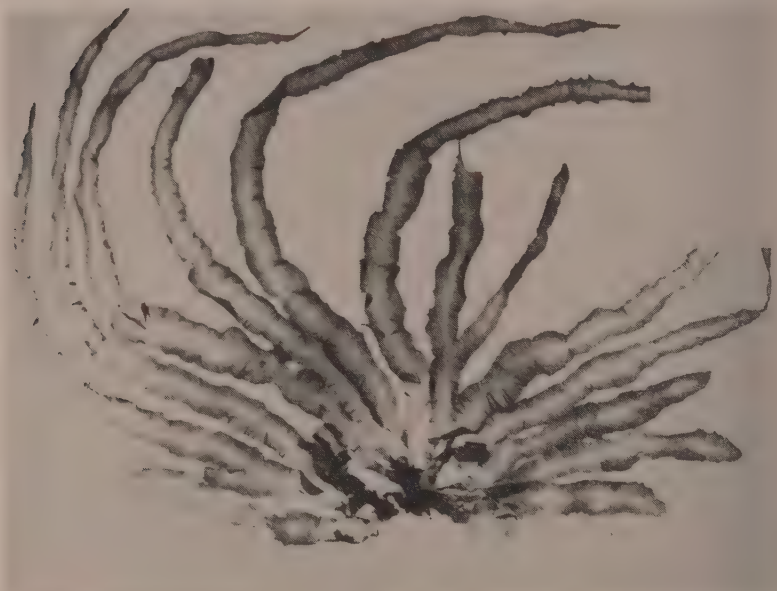


FIGURE 17. *Ulva fasciata*, photograph of an herbarium specimen. X 0.2.

the disk at the center is a crown of projections arising from the top of the stipe, the corona superior, each segment of which bears a colorless hair. A similar structure, the corona inferior, is located on the under-side of the disk, but hairs are lacking. Spores borne within the disk rays (sporangia), 200-500 in each. Plants typically in dense clusters on shells and stones.

General Distribution.—Bermuda, Florida, West Indies, Caribbean Sea.

N.W. Florida.—Tampa Bay to Dog Island and St. Teresa, Franklin County, and probably to Pensacola.

References.—Taylor 1928, p. 67; Collins 1909, p. 378.

Acetabularia farlowii Solms

Figure 9 A-B

Differs from *A. crenulata* in having a smaller disk (4-7 mm diameter) shorter stipe (1-2 cm high) and fewer rays (20-30) which

are lightly coherent, often separated. Two hair scars on each segment of corona superior, spores 40-120 per ray.

General Distribution.—Florida.

N.W. Florida.—Continuous from Tampa Bay to Franklin County. In a collection from Ozone Shores, Pinellas County, the plants agreed with Howe's description in most respects but bore only 10-20 aplanospores per ray, the spores measuring from 140-180 microns in diameter. Other specimens from the Rock Islands off Taylor County were up to 5 cm tall.

References.—Howe 1905, p. 576; Collins 1909, p. 379; Taylor 1928, p. 67; 1960, p. 105.

Acicularia schenkii (Möbius) Solms

Figure 8 A-B,E-G

Similar to *Acetabularia crenulata*, the stipe 1-3 cm high bearing a flattened disk about 6 mm in diameter and with 30-50 closely united rays. Corona superior 13 mm in diameter with 2 hair scars on each segment. Spores 60-80 microns in diameter, 100-200 per ray, embedded in lime.

General Distribution.—Bermuda, Florida, West Indies, Caribbean Sea, South America.

N.W. Florida.—Dredged in 25-30 feet of water near buoy 26 about 10 miles S.E. of Alligator Point, Franklin County; secured by diving in 8-10 feet of water in *Thalassia* beds about 4 miles E.S.E. of St. Marks light, Wakulla County; probably continuous from Tampa Bay.

References.—Collins 1909, p. 380; Taylor 1928, p. 68; 1960, p. 107, pl. 6, fig. 11.

Batophora oerstedii J. Agardh

Figure 7E, J

Plants with an erect axis, usually 4-6 cm high, bearing whorls of monosiphonous branches which are dichotomously branched to 6 or 7 series, each tapering to smaller diameter, the whorls of branches 0.5 to 1.0 mm apart on the axis. Green, oval sporangia borne at the ends of the second to fourth series, mostly 700-850 microns in diameter containing spores 40-45 microns in diameter. Plants not calcified.

General Distribution.—Bermuda, Florida, West Indies, Caribbean Sea.

N.W. Florida.—Continuous from Tampa Bay to rocky areas about 5

miles E.S.E. of St. Marks light, Wakulla County. Since this species has not been found in shallow water with its usual associate, *Acetabularia crenulata*, it is presumed that it is reaching its northern limit in the Alligator Harbor vicinity and is thus confined to deeper water where winter temperatures are not as low as inshore.

References.—Howe 1905, p. 579; Collins 1909, p. 383; Taylor 1928, p. 68.

Dasycladus vermicularis (Scopoli) Krasser

Figure 7 D,F

Similar to *Batophora oerstedii* except that the whorled branchlets are more closely placed, of fewer series (3-4) and borne from the base of the main axis upwards so that the main axis is sessile. Solitary gametangia are produced on the second series of branchlets.

General Distribution.—Bermuda, Florida, West Indies, Caribbean, Mediterranean and Adriatic Seas.

N.W. Florida.—In shallow water at Keaton's Beach, Taylor County. Probably continuous from Tampa Bay though not collected elsewhere within the range of this study.

References.—Taylor 1928, p. 69; Howe 1918, p. 498.

Phylum CHRYSOPHYTA
Order HETEROSIPHONALES
Family VAUCHERIACEAE
Vaucheria thuretii Woronin

Plant of branched coenocytic filaments producing a small cushion and usually accumulating muddy sediment among the erect branches. Filaments to 80 microns in diameter, antheridia sessile, straight, ovoid, 50-70 microns in diameter; oogonia spherical, obovoid or pyriform, usually on a one-celled stalk, about 200 microns in diameter. Starch not stored. Since the genus *Vaucheria* has been included in the *Chlorophyta* in the past, it is included here, although it is now in the division *Chrysophyta* (Smith 1955).

General Distribution.—Europe, Maine to New Jersey, Florida.

N.W. Florida.—At Way Key, Cedar Keys (Det. by Dr. Francis Drouet). The genus occurs also around the mouth of the Ochlockonee

River, Franklin County, but material with gametangia was not obtained.

References.—Madsen and Nielsen 1950; Collins 1909, p. 424.

SUMMARY

A study was made of the marine *Chlorophyta* of the upper west coast of Florida from Tampa Bay to Pensacola based upon numerous collections by the writers and others, and upon records from certain herbaria and the literature. Sixty-five species are recorded, 33 of which are newly reported from the area north of Tampa Bay.

In general, species found as far north as Tampa Bay may be expected to have a continuous distribution northward and around the Gulf to Texas and Mexico, as minimum winter temperatures of the water seem to be sufficiently similar at intermediate depths offshore to permit development where salinity fluctuations are unimportant. The algae of the northern Gulf are not limited to those characteristic of brackish waters and salt marshes. These types are conspicuous along shore, but a wide variety of stenohaline and tropical species occurs at depths of 15 to 100 feet or more throughout the area wherever the bottom provides a suitable substrate.

While the present paper extends the known range of many species of green algae in the Gulf of Mexico, it represents only a modest beginning toward a thorough knowledge of the distribution of this group along the west coast of Florida.

An artificial key, illustrations and a systematic list of species with descriptions and habitat notes are given for the species of marine green algae now known for the area.

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PRIMARY PRODUCTION IN THE SOUTHWEST SARGASSO SEA JANUARY-FEBRUARY, 1960¹

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ABSTRACT

Primary production was measured at 22 stations in the Sargasso Sea South of Bermuda during the winter of 1960. The mean rate of production was 0.05 g carbon assimilated/m²/day as measured by C¹⁴ uptake and 0.09 as estimated from chlorophyll and radiation measurements. The low values appear to be typical of the tropical Atlantic and reflect nutrient impoverishment resulting from stratification of the surface layers.

Five-fold variations in solar radiation had little effect upon and showed no correlation with rates of primary production indicating that light is not a limiting or contributing factor at those latitudes.

There are indications of a diurnal periodicity in C¹⁴ uptake and chlorophyll concentrations, twenty-four hour C¹⁴ uptake experiments initiated in daytime giving lower values than those begun at night while lower chlorophyll values were measured at night than during daylight.

INTRODUCTION AND METHODS

During the winter of 1960 the authors participated in an oceanographic cruise (R. V. CRAWFORD 37) the primary purpose of which was the investigation of hydrographic conditions in the Sargasso Sea southwest of Bermuda. A total of 33 stations were occupied from Bermuda southeast to approximately 28°N, 48°W and thence southwest to the Windward Islands (Figure 1). Temperatures, salinity and dissolved oxygen (0-260 meters) were measured aboard ship and frozen samples were returned to the Bermuda Biological Station for analysis of nitrite, nitrate and phosphate. Daily incident radiation was measured with an Epply pyrheliometer throughout the cruise.

At 22 stations, including two where hydrographic measurements were not made, primary production was measured by a simulated *in situ* C¹⁴ technique. Water samples were collected with a non-metallic sampler from depths to which 100, 50, 25, 10 and 1 per cent of the incident radiation penetrated (as determined with a Weston submarine

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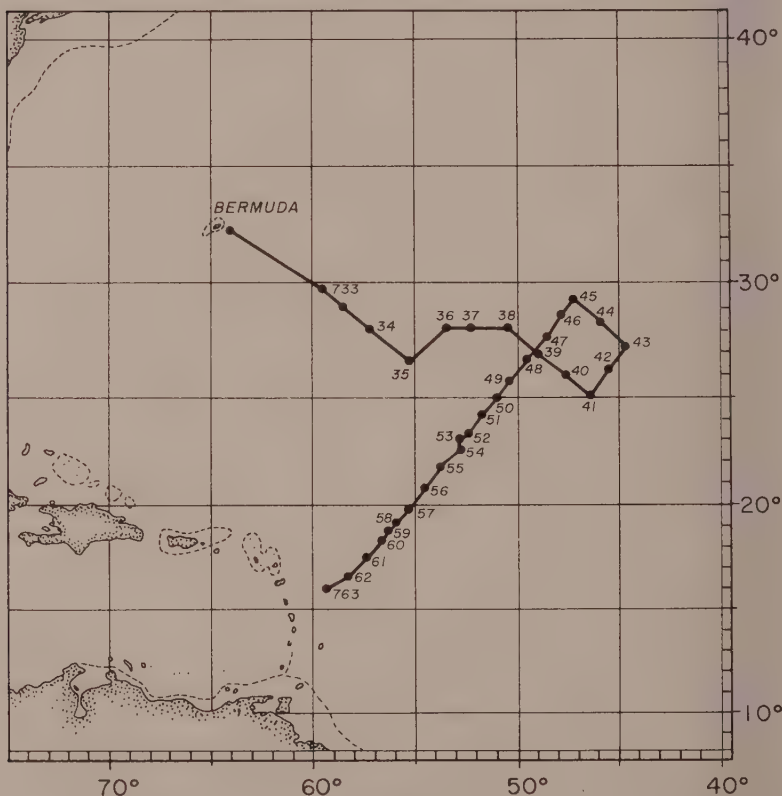


FIGURE 1. Cruise plan of CRAWFORD 37 showing station locations.

photometer). These were dispensed into pyrex bottles, ca. 20μ curies $C^{14}O_3 =$ were added, and the bottles were placed in a water-cooled incubator and covered with Kodak wratten neutral density filters which transmitted the same fraction of sunlight to which the water had been naturally exposed. The bottles were so incubated for 24 hours after which treatment was essentially as described by Steemann Nielsen (1952). From the same depths four-liter water samples were collected and filtered for subsequent determination of chlorophyll *a* by the method of Richards with Thompson (1952) as modified by Creitz and Richards (1955). Production was then calculated from chlorophyll

a concentration and radiation by the method of Ryther and Yentsch (1957). Productivity data by the C^{14} and chlorophyll methods are interpreted as measuring net and gross primary production respectively (Ryther and Yentsch, 1958).

PRODUCTION IN RELATION TO LATITUDE

The results of these studies are essentially the same as were found in March, 1959, on a short cruise from Bermuda south to latitude 25° , a distance of about 500 miles (Ryther and Menzel, 1960). At that time high production (ca. $1.00 \text{ g carbon/m}^2/\text{day}$ by the C^{14} method) was observed near Bermuda where the waters were isothermal and mixed to depths well in excess of the euphotic zone. Just 150 miles south of Bermuda, however, the surface waters were stratified and net production was about $0.10 \text{ g carbon/m}^2/\text{day}$, an order of magnitude lower than that found in the Bermuda area.

The investigations made during CRAWFORD 37 were earlier in the winter, covered a much greater area, and were more intensive than those referred to above. On the whole, they confirm the hypothesis

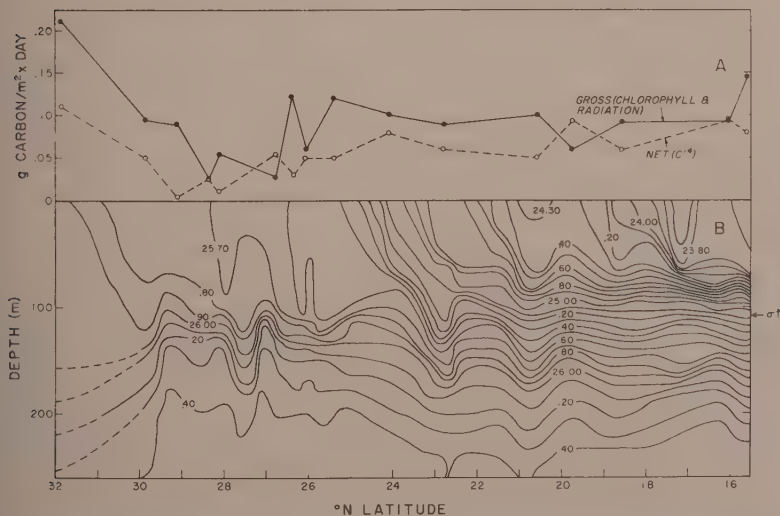


FIGURE 2. A. Gross (closed circles, solid line) and net (open circles, broken line) primary production. B. Vertical profile of density (σ_t) in the surface water as related to latitude on CRAWFORD 37.

that, due to stratification of the euphotic layer (0-100 meters), winter production in the tropical Atlantic is low and relatively constant.

The highest levels of net and gross production (0.12 and 0.21 g carbon /m²/day respectively) were observed just off Bermuda (32°N). South of this, from about 30°N to 15°N, production fell to appreciably lower values which showed minor fluctuations but did not vary latitudinally in any obvious systematic way (Figure 2 A). Mean net and gross production for all stations excluding the first were 0.05 and 0.09 g carbon/m²/day respectively.

The vertical density profile from 0-260 meters illustrates that the euphotic layer is unstratified in the Bermuda area, rather weakly stratified from 30° to about 25°, and very strongly stratified from there to the southern end of the section (Figure 2 B). Apparently the presence and not the degree of stratification is the important controlling factor since there appears to be little correlation between the intensity of stratification and productivity south of Bermuda.

The stratification of the sub-surface waters south of 25° is partly thermal but is also due in large part to the presence of a layer of high salinity water, often exceeding 37.00‰, centered at about 100 meters. This water is believed to be formed in winter at the surface roughly in the area described by 25-30°N, 45-50°W due to the combined effects of cooling and evaporation. This denser water sinks to about 100 meters and spreads to the south and west (L. V. Worthington, personal communication). The concerted effort made in that area (Figure 1) represented an unsuccessful attempt to observe this convergence in action, but some of the high salinity water had apparently been formed earlier in the season.

THE EFFECTS OF VARYING INTENSITIES OF INCIDENT RADIATION

Day-to-day changes in the weather caused incident radiation to vary during the cruise between 70 and 380 g cal/cm²/day. Within this five-fold range, net production as measured by C¹⁴ uptake showed very little change and no correlation with radiation. Gross production, determined from chlorophyll and radiation, necessarily showed some relation to the latter, but variation in chlorophyll concentration, quantitatively more important in the calculation, prevented a close correlation even here (Figure 3). These observations substantiate the hypotheses that, although light may be critical at higher latitudes, nutrients are the primary limiting factor in the tropics and almost

completely obscure any minor effects of varying radiation (Steemann Nielsen and Jensen, 1957).

DIURNAL PERIODICITY IN NET AND GROSS PRODUCTION

Excluding the first station off Bermuda, 21 productivity measurements were made, 12 during the daylight hours and 9 at night. Of the

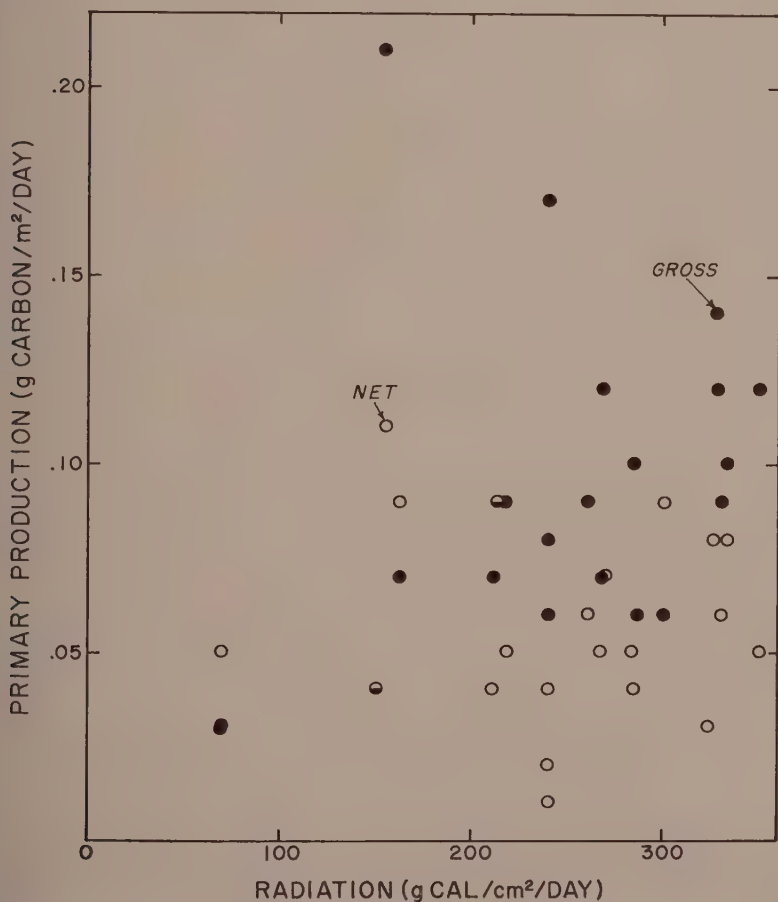


FIGURE 3. Gross (closed circles) and net (open circles) primary production as related to incident solar radiation.

12 daylight stations, 9 (75%) of the resulting C^{14} productivity values fell below the mean for all the stations, while 8 (67%) of the chlorophyll-based productivity values exceeded the mean. Of the 9 night stations, 6 (67%) of the C^{14} values exceeded the mean and 6 (67%) of the chlorophyll productivity values fell below the mean. While the quantitative aspects of these ratios are probably meaningless, the consistency of their trend suggests that C^{14} uptake is higher when experiments are begun at night than in the day while chlorophyll behaves in the opposite manner. It may be pointed out here that, although gross production is determined from the instantaneous concentration of chlorophyll at the time of sampling, net production is based upon C^{14} uptake over 24 hours. We had assumed that 24-hour measurements would avoid the problem of a diurnal periodicity in C^{14} uptake as described by Doty and Oguri (1957), Yentsch and Ryther (1957) and Shimada (1958). Apparently, however, daily C^{14} assimilation is dependent at least to some extent upon the time of day the measurements are initiated. This is one explanation for the minor variations in productivity in a region which appears to be otherwise homogeneous.

Since daily C^{14} uptake was measured at five intensities of radiation and we have chlorophyll concentrations from the corresponding depths at each productivity station, it is possible to plot C^{14} uptake per unit of chlorophyll for a wide range of light intensities. When this is done separately for all stations occupied at approximately 0800, 1200 and 2000 hours (Figure 4) it is clear, despite some unaccountable departures, that the majority of points describe a relationship between the two variables which varies appreciably throughout the day. This relationship was consistent from station-to-station with no indication of geographical variability. The six low carbon/chlorophyll ratios at high radiation values at 2000 were surface samples which may reflect the effects of light inhibition in those samples. Otherwise, no systematic variations with depth could be detected.

We have observed a similar change in the C^{14} /chlorophyll relationship from season to season and from year to year at a single station off Bermuda (Menzel and Ryther, 1960). Although this could not be explained, it was believed to have resulted from some systematic change in either C^{14} uptake or chlorophyll relative to the other. We are no nearer an explanation of this phenomenon now, but in view of what appears to be independent variations in C^{14} assimilation and chlorophyll at the same time but in opposite directions, inconsistencies in the

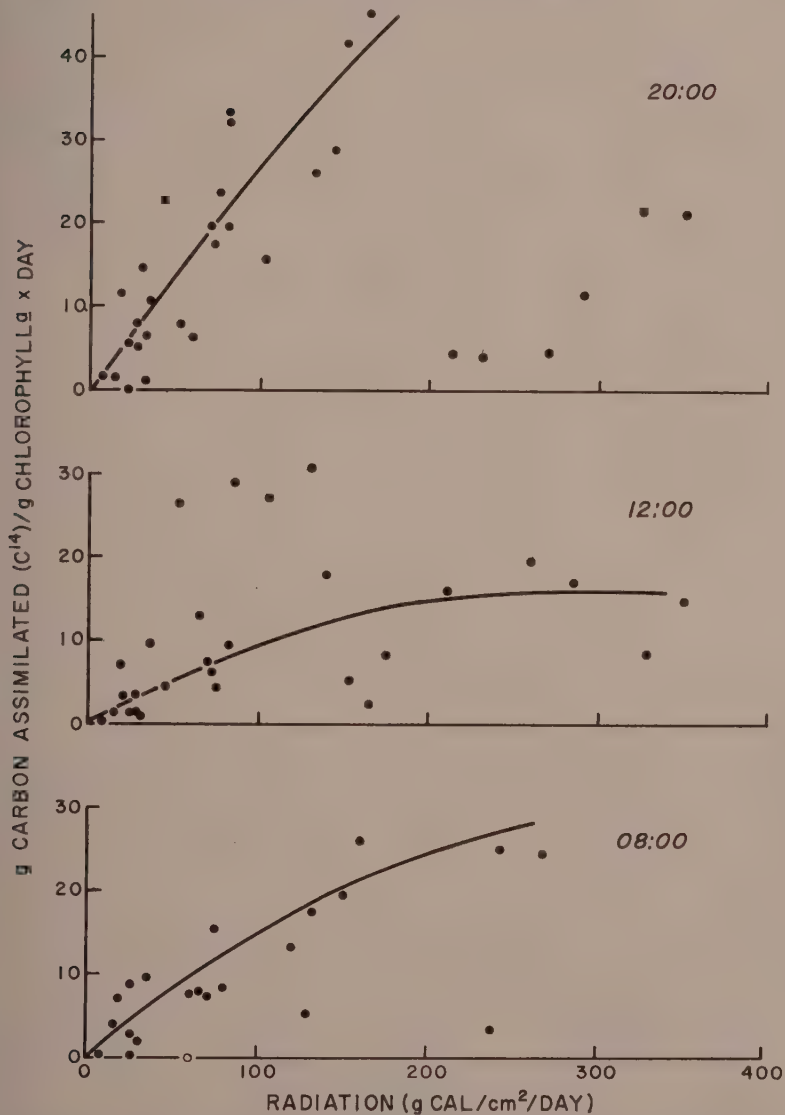


FIGURE 4. The ratio of C¹⁴ assimilation/chlorophyll as a function of the intensity of solar radiation in experiments initiated at different times of day.

relationship between net and gross production, as determined here, may result from changes in both chlorophyll and C^{14} uptake relative to each other. While these diurnal and seasonal irregularities in the criteria for determining productivity clearly warrant further investigation, the errors which they introduce appear to be of second order magnitude and are important only where very precise knowledge is required of the magnitude and variability of primary production.

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A NEW SPECIES OF *PSEUDOBRYOPSIS* FROM PUERTO RICO

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ABSTRACT

This is the first report of the occurrence of the genus *Pseudobryopsis* Berthold in the West Atlantic where it was collected in Puerto Rico in 1957. The material represents a new species which is described and named *P. longipedicellata*.

During April, 1957, the junior author collected a considerable number of marine algae around the island of Puerto Rico. Knowing that the senior author was interested in the marine algae of this area, having collected quite extensively here during the academic year of 1941-1942, Professor Piferrer sent him duplicates of his collections for identification, or verification of his own determinations. Among these was a small green alga which superficially resembled a *Bryopsis*, but upon microscopic examination proved to be an entirely different plant.

It grew to a maximum height of about 5 cm and consisted of a few rather coarse, non-septate filaments with apical growth from an entangled rhizoidal base. These filaments averaged about 0.4 mm in maximum diameter and branched sparingly subdichotomously mostly above the middle. They were densely beset all around, except toward the base, by numerous slender ramuli which branched sparingly subdichotomously also. On the basal portion, these ramuli bore relatively large, pedicelled, broadly ovate reproductive bodies with dense contents, which were assumed to be sporangia or gametangia.

From the general appearance of this alga, it was concluded that it might represent a *Pseudobryopsis*; but, being unfamiliar with this genus and not having any authentic specimens available, a specimen was sent to Dr. Papenfuss of the University of California with a request for his opinion regarding it. With the assistance of one of his students, Mr. Fan, they made a study of it and reported that it was undoubtedly a *Pseudobryopsis*, but that it seemed to differ in certain characters from all other species of this genus so far described. Since they—especially Mr. Fan—made an intensive study of this alga in comparison with other species of this genus, it was our hope that they would

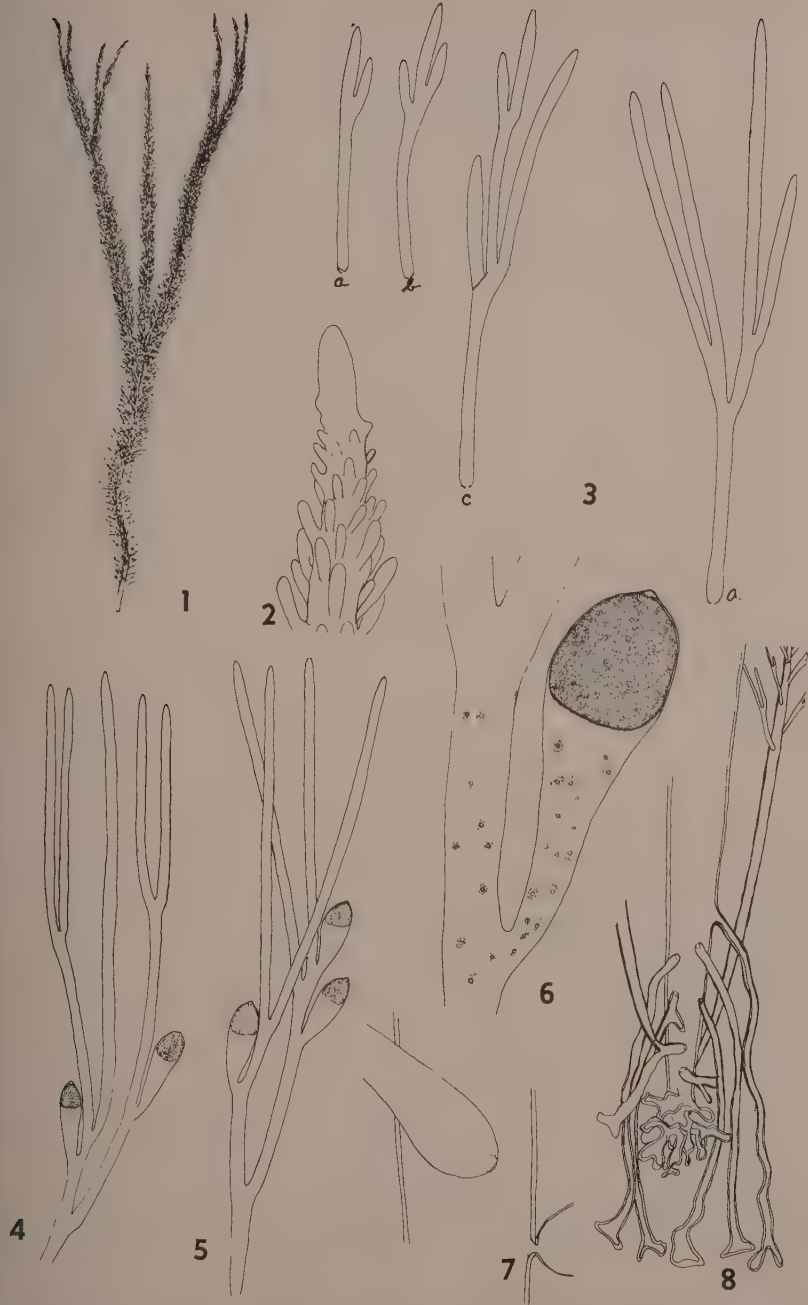
describe and name it, but this they declined to do because of other duties, and kindly sent us extensive notes regarding the characteristics of this entity in comparison with others.

At present, 7 species of *Pseudobryopsis* have been described from various regions of the world. The type was first described from the Mediterranean by J. Agardh (1842) as *Bryopsis myura*. In 1881, Berthold transferred this to a new genus *Pseudobryopsis*. The 6 other species, and their respective type localities, are as follows: *P. mucronata* Børg. (1930), Bombay; *P. hainensis* Tseng (1936), Hainan; *P. papillata* Nasr (1944), Red Sea; *P. mauritiana* Børg. (1948), Mauritius; *P. oahuensis* Egerod (1952), Oahu, Hawaii; and *P. parva* Dawson (1954), Nha Treng, Viet Nam. All of these, except the last, were discussed by Egerod (1952). To these may now be added another which represents the first record of this genus in the West Atlantic.

Pseudobryopsis longipedicellata n. sp.

Plantae 5 cm aut minus altitudine, compositae ex paucis centralibus atque subbifurcatis fibris, parece 4 mm diametro; ramuli radiatim ordinati, numerosi, graciles atque subbifurcati, circa 2 mm longitudine, prope 38μ diametro, ad situm a basi primi ramuli raro divisi; chloroplasti discoidei, 7μ diametro, pyrenoide centrale; gametangio 1-2, ad situm primi aut raro secundi ramuli, longo-pedicellata, lato-ovato, $61-83\mu$ longitudine, 5067μ latitudine, ad apicem mucronata; pedicellus 120 u aut minus longitudine, ad basem, gametangi gradatim amplificatus, raroisepatus. Cellulae fertiles non vident.

Plants consisting of a few erect central filaments up to 5 cm in height, originating from a common rhizoidal base, approximately 0.4 mm in maximum diameter, sparingly repeatedly branching subdichotomously mostly above the middle, sometimes bearing adventitious branches near the base, densely beset radially with slender ramuli, except in the basal portion; ramuli spreading to ascending above, up to 2 mm long, sparingly repeatedly branching subdichotomously above the basal portion, abruptly inflated above the narrow, non-septate base, tapering gradually outward to obtuse apices, approximately 38μ in maximum diameter, transformed at base of axial filament into rhizoidal holdfasts, non-septate except occasionally at base of one of the primary branches; chloroplasts rounded discs, approximately 7μ in diameter with a distinct pyrenoid; 1-3 gametangia borne on the basal portion of each ramulus, the first usually at or



FIGURES 1-8. *Pseudobryopsis longipedicellata* n. sp. 1. Habit of part the plant. 1.8 X. 2. Apical portion. 272 X. 3, a,b,c. Development of ramuli. 64 X. 4, 5. Ramuli with gametangia. 64 X. 6. A gametangium. 272 X. 7. Portion of axial filament with bases of ramuli, 272 X. 8. Base of axial filament showing rhizoids, ramuli-rhizoids, and adventitious branches from axial filaments. 272 X.

slightly above the first forking (rarely below), mostly singly between the dichotomies, rarely two; pedicel up to 120μ long, gradually enlarging upward to the base of the gametangium, rarely septate at base in the first one; gametangium broadly ovate, papillate at apex, $67-83\mu$ long, $50-67\mu$ broad; reproductive cells not seen.

Localities: Boca de Congrejos, near San Juan, and Gata Island, off La Parguera. TYPE: collected by M. Diaz-Piferrer, on rocks washed by waves, Boca De Congrejos, April 7, 1957; deposited in the Herbarium at Duke University; isotypes at Universidad de Oriente, Santiago, Cuba, and University of California, Berkeley. Plants at Gata Island grew on roots of *Rhizophora Mangle* L.

Since the plants collected in 1957 did not have mature gametangia, a search was made for this interesting alga by the senior author in the spring of 1958, but without success. The junior author had the same experience during the academic year of 1958-1959, when he was stationed at the Colegio de Agricultura y Artes Mecanicas, Mayaguez, P. R., even though he searched for it in the same localities where he found it in 1957. Apparently this is one of those marine algae which "comes and goes." It seems also strange that it has not been found before around Puerto Rico by other collectors, as well as in the nearby American Virgin Islands, and other islands of the West Indies.

In comparing this species of *Pseudobryopsis* with all other species of this genus so far described, it differs more or less from all of them. In size, it differs most from *P. parva* which is only 5-7 mm tall, but is smaller than *P. mauritiana* which, according to Børgesen, was 10 cm and possibly more in length. In the branching of the axial filament it differs from *P. parva* and *P. oahuensis* which are mostly unbranched; and from some of the others, such as *P. mauritiana* and *P. mucronata* which are irregularly branched. In the branching of the ramuli, it differs from those in which they do not branch, as in *P. parva* and *P. oahuensis* and those which have irregular branching, as in *P. mauritiana* and *P. mucronata*, but resembles *P. papillata* which is repeatedly subdichotomously branched.

By eliminating those in which ramuli do not branch, comparisons are made with others in regard to position of gametangia. In the new species these are borne on the lower portion of the ramuli (Fig. 4, 5), the first usually at or slightly above the first dichotomy (rarely below) on one branch and the second further outward on the other branch, while the third is usually at the second dichotomy. The gametangia

are evidently never "terminal" as has been said of *P. mucronata* and *P. mauritiana*. Of course, whether the gametangia are terminal or not may be considered relative, since, as in the new species, the gametangia are terminal on a distinct pedicel of variable length. However, although this pedicel may be considered a modified branch, it is distinctly shorter and otherwise different from normal branches. The outstanding difference between the new species and all other known species is the pedicelled gametangia. In other species they are mostly sessile on the branches. For this reason, we have selected the epithet *longipedicellata* for the name of this new species.

The authors wish to acknowledge with thanks the assistance received from Dr. G. F. Papenfuss and Mr. Kung-Chu Fan of the University of California, and from Dr. F. A. Wolf of the Department of Botany, Duke University, for the Latin diagnosis.

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ECOLOGICAL EFFECTS OF SEWAGE POLLUTION IN BISCAYNE BAY, FLORIDA: SEDIMENTS AND THE DISTRIBUTION OF BENTHIC AND FOULING MACRO-ORGANISMS¹

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ABSTRACT

Evidence is presented on both harmful and fertilizing effects of sewage in northern Biscayne Bay, Florida, as determined by the quantitative distribution of benthic and fouling macro-organisms. Harmful effects, as indicated by absence of benthic life, were limited to 3 of 65 stations within 200 yards of sewage sources in greater than average depths. Absence of spermatophytes at many stations may have been due to pollution. Fertilizing effects, as measured by abundance of benthic life, were most pronounced in a narrow band roughly 200 to 600 yards from sewage sources in shallow water with good tidal circulation where the bottom consisted of firm sandy mud (Md. 0.125 - 0.500 mm.). Indicator organisms of both effects were present. Using in part the principles for describing bottom communities developed by Thorson, two plant-animal associations were found to occupy distinct benthic zones, one primarily in highly polluted areas and the other in less polluted areas. The initially settling fouling organisms in highly polluted waters (greater than 10,000 MPN) were mainly tubiculous amphipods. Sediments have been analyzed for median grain diameter, sorting coefficient, and oxygen uptake measured in the Warburg respirometer. Unusually high oxidizable organic content in sediments was limited to 7 of 65 stations, five of which had median diameters of less than 0.100 mm.

INTRODUCTION

The sediments, bottom-dwelling macro-organisms, and selected fouling organisms have been studied in northern Biscayne Bay, Florida, in order to evaluate ecological effects of sewage pollution. The study was initiated by Dr. F. G. Walton Smith, Director of the Marine Laboratory, University of Miami, several years ago when it became known that the City of Miami intended building a sewage disposal plant which would render the bay free of contamination, thereby providing an unusually good opportunity for comparison of ecological conditions during and after heavy pollution. The plant was completed in December, 1956, after which the untreated sewage which was formerly emptied into the bay was diverted to the plant for treatment. This paper deals with conditions prior to plant acti-

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vation. A study is now in progress to determine ecological changes in the area four years after construction of the plant.

The work reported in this paper is part of a comprehensive pollution study which includes hydrographic, bacteriological, chemical, and other biological aspects. The detailed hydrography (including salinity, oxygen and current data) and the geomorphology of the bay were described by Hela, Carpenter and McNulty (1957). Application of Ketchum's Intertidal Volume Concept to the distribution of coliform bacteria, chemical nutrients and volumes of zooplankton were reported by McNulty, Reynolds and Miller (1960). Oxygen demand and organic carbon determinations in sediments were studied by Lynn and Yang (1960). The present paper is devoted to the orientation of benthal macroorganisms to water pollution and to organic content and particle sizes of the sediments. Also included is information on the zonation of fouling organisms with respect to pollution.

Published information on Biscayne Bay up to 1955 is summarized by Morrill and Olson (1955) and by Joseph and Nichy (1955). Two geological studies of bay sediments (Vaughan, 1910) and (Thorp, 1935) cover almost entirely areas to the south of the study area. The ecology of plankton and fouling organisms of the bay, including polluted areas, was studied by Smith, Williams and Davis (1950). The fouling complex was reported in detail by Weiss (1948). Moore and Frue (1959) have provided a description of seasonal and annual fluctuations in settlement and growth of the three major species of barnacles in northern Biscayne Bay. Other biological aspects of the area have been studied by Greenfield (1952) and by Meyers (1953, 1954) who reported on the distribution of marine borers and marine fungi, respectively. A comprehensive study of benthic macro-invertebrates south of Rickenbacker Causeway by Moore, McNulty and Work is nearing completion. There have been no previous studies of benthic macro-organisms of the area north of Rickenbacker Causeway nor has there been a previous attempt to provide synoptic data on the fouling organisms. There are abundant data available on pollution in the area from both the Florida State Board of Health survey (Minkin, 1949) and from Marine Laboratory bacteriological studies (Reynolds, 1955).

Field work was conducted originally as an adjunct of hydrographic studies and later as an intensive study of benthal and fouling ecology (McNulty, mimeographed reports of 1955, 1956, 1957). Those who have assisted with the field work from time to time are Clarence A.



FIGURE 1. Station locations.

Carpenter, Jr., Jonathan Baskin, Scott McGowan, and various graduate students. General supervision has been exercised by Dr. F. G. Walton Smith assisted by Drs. Hilary B. Moore and C. E. Lane. Dr. Gilbert L. Voss has given considerable assistance and advice, particularly on systematics of benthic animals. Assistance with identification of spermatophytes and algae was given by Dr. Robert H. Williams. Donald G. Ahearn, graduate assistant, worked primarily on identification of the amphipods; when submitted to the U. S. National Museum for checking, Dr. Clarence R. Shoemaker kindly made the determinations. All initial identifications have been made by the author, with the assistance indicated above plus valuable consultations with Mr. Robert C. Work on mollusks and Mr. Lowell P. Thomas on ophiurans.

Northern Biscayne Bay is classified as a positive, shallow, tidal bar-built estuary. Station locations and key geographical features are shown in Figure 1. Average depths increase gradually from about three feet just south of 79th Street Causeway to about nine feet just north of Rickenbacker Causeway. Several channels have been dredged, the most important being the Main Ship Channel (Government Cut), controlling depth 28.5 feet. The Intracoastal Waterway Channel, eight feet in depth, roughly parallels the Miami Shoreline. Additional eight-foot channels parallel Miami Beach and interconnect the many residential islands. Benthic sampling was not done in channels unless absolutely unavoidable.

The addition of sewage in the aquatic environment often results in zonation of the macro-organisms. The following three major zones are generally recognized: (1) a zone of no life (or relatively scarce life) immediately adjacent to the outfalls; (2) a zone of abundant life in which a few species are found in greater than normal abundance outward from the zone of no life; and (3) a zone of normal abundance of many species characterizing clean, unpolluted areas. This general pattern has been observed many times in fresh water (Patrick, 1949); Gaufin and Tarzwell, 1956), but it has been demonstrated only a few times in marine and estuarine waters. Apparently the first marine study which showed this effect clearly was that of Blegvad (1932) off Copenhagen in the Sound. Petersen grab samples taken at varying distances from sewage outfalls showed that conditions injurious to the bottom fauna occurred only within a comparatively small radius of 100 to 200 meters around the outfalls. Immediately beyond this radius Blegvad found a comparatively rich fauna dominated by bi-

valves, especially *Cardium edule*, *Mya arenaria*, and *Macoma baltica*, often occurring with *Zostera*. Polychaetes, dominated by *Scoloplas armiger*, were unusually abundant at only one of several outfalls. Beyond this zone Blegvad found that the benthic fauna returned to normal abundance and number of species. Comparable zonation has been described in California by Filice (1954a and 1954b) for San Pablo Bay and for San Francisco Bay estuary. Similar zonation is evident in the results of Reish in California, although in his most recent work on Los Angeles-Long Beach Harbor, the pollution is mainly industrial (Reish, 1959). Baughman's annotated bibliography on oysters (Baughman, 1948) contains many references to pollution, most of which deal with industrial wastes; none of these treat sewage as an ecological factor in which the objective of the study is to define the relationship of the flora and fauna generally to sewage. Doudoroff & Warren (1957) emphasize that widely distributed sessile or sedentary organisms should be the most useful indicators of past aquatic conditions, but that the water quality requirements of most of the "indicator organisms" have never been thoroughly investigated. What appears to be the most effective attempt to do this from field data is the study of Gauvin and Tarzwell (1956). These authors conclude that the distribution of organisms found in a pollution gradient should be analyzed in groups (associations) according to their morphological adaptations and physiological requirements. This approach has been utilized with outstanding success in past studies on marine level bottom animal communities (Thorson, 1957). The present paper includes an attempt to apply the community analysis method of Thorson to the distribution of plants and animals in northern Biscayne Bay.

METHODS

Benthic biological sampling has been done with a Petersen grab which covers approximately 0.074 m^2 (at 76 stations). The choice of making three grabs per station, thus sampling an area of about 0.222 m^2 per station, represented a compromise (arrived at largely by practical necessity) between a totally inadequate sample of smaller size and a more truly accurate sample of larger size. Samples were washed in a box containing monel screens with aperture size about 0.7 mm .

Sediments were analyzed for grain size and for oxygen demand. Field sampling was accomplished with a simple coring device developed specifically for this work. It consisted of a standard plastic



FIGURE 2. Horizontal distribution of MPN (after Minkin, 1949).

coring tube (length 10.5 in., O.D. 2 in., thickness 1/16 in.) secured to a cylindrical length of wood by three brass supports. Resting on top of the plastic coring tube was a sponge rubber ball whose diameter was slightly greater than that of the tube. The ball was made to fit precisely the top of the tube by rotating fine-grain sand paper between ball and tube in order to provide a water-tight seal. Lead weights attached to the ball by heavy wire caused the ball to remain seated at the top of the tube during descent of the device to the bottom. Attachment of a length of calcutta bamboo permitted sampling to depths of 30 feet. A photograph and description of the device appear in a mimeographed report by the writer (McNulty, 1957). Description of an improved model appears in Lynn and Yang (1960). Sediment was extruded from the coring tube by means of a tight-fitting rubber plunger so as to deliver a sample representing the top one inch of sediment.

Particle size fractions were obtained by wet sieving through Tyler standard screens having mesh openings of 2.0, 1.0, 0.500, 0.246, 0.125 and 0.062mm. The residue, caught in a bucket placed under the sieves, underwent accelerated flocculation upon dropwise addition of concentrated HCl, and later was deposited on filter paper by suction filtration in order to obtain dry weight of silt and clay combined. Semi-log graphs of cumulative per cent composition permitted graphical determination of median diameter and sorting coefficient (Krumbein and Pettijohn, 1938).

A relative measure of the readily oxidizable organic material in surface sediments was obtained by recording the oxygen uptake of known quantities of sediment in the Warburg respirometer. This was done by delivery of a precise volume of mud into the reaction vessels and also into 2 ml flasks for slow drying and later determination of specific gravity (American Public Health Assoc., 1946, p. 353) and moisture content. All Warburg determinations were made at 25°C (the approximate average temperature in nature), and at a shaking rate of 100 per minute. After equilibration for 10 to 20 minutes, oxygen uptake after three hours was recorded and used in the determination of 0.2 per gram of dry sediment per three hours.

Synoptic data on predominant fouling organisms were obtained at 57 stations by planting surveyor's stakes in the mud, exposing them for two weeks, and later examining them for species and quantities of attached organisms. The purpose of the experiment was to obtain comparative data on fouling at the same stations used in the hydro-

graphic, bacteriological, chemical and benthic work. Each stake was fitted with a 10 to 20-foot length of plastic line (commercial plastic clothesline) on the bitter ends of which were attached 3 to 5 large iron washers. The stakes were planted by means of a wooden hollow holder attached to various lengths of 2 x 2 inch lumber, and were pounded into the sediments using a sledge hammer. Recovery of the stakes was accomplished by an instrument consisting of a length of iron pipe to which 4 or 5 three-pronged snatch hooks were attached. This object was dragged over the bottom in the vicinity of each stake and in 1 to 3 passes snagged the plastic line. This method worked satisfactorily over bottom essentially devoid of heavy vegetation. The recovery rate was 84 per cent. A photograph of the stake driver and a stake with plastic line attached appears in McNulty (1957). Earlier studies, involving determination of volumes of fouling substance which attached to glass panels over a one-month period, were conducted by suspending 8 x 9 inch panels subtidally in simple wooden holders from conveniently located day markers or sea walls at 15 stations.

POLLUTION, HYDROGRAPHY AND SEDIMENTS

All results have been interpreted in terms of distribution of the pollution, shown in Figure 2. This figure is taken from the Florida State Board of Health pollution survey (Minkin, 1949), which in its essentials corresponds with later bacteriological and hydrographic results (Reynolds, 1955; Hela *et al.*, 1957), except that the later studies show clear evidence of higher average MPN counts and lower dissolved oxygen contents. The detailed maps of the horizontal distribution of salinity and oxygen in Hela *et al.*, indicate clearly the following points: (1) except in the Miami River mouth and vicinity, average salinities were between 25 and 32.5‰ throughout the area with minima reaching less than 17.5‰ at about 10 per cent of the stations in the immediate vicinity of the river; (2) surface oxygen concentrations remained well above 40 per cent saturation generally throughout the bay except in the river mouth where conditions were septic.

Table 1 summarizes results of physical studies of sediments. The figures for median grain diameter and log sorting coefficient are rounded off to two significant figures because by the graphical method used it was not possible in all cases to determine the third place with accuracy. The data are grouped by east-to-west transects where pos-

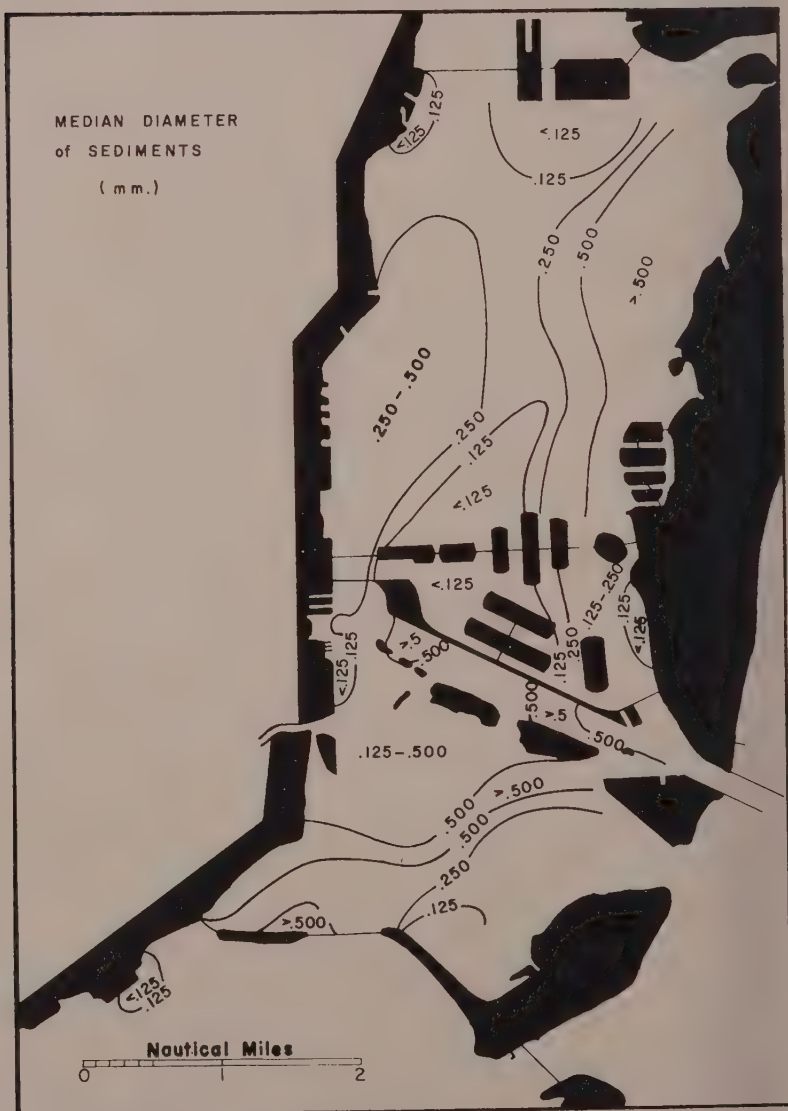


FIGURE 3. Horizontal distribution of median diameter of sediments.

TABLE 1

SUMMARY OF SEDIMENT DATA FROM NORTHERN BISCAYNE BAY

Station	Median Grain Diameter (mm.)	Log. Sorting Coefficient	Specific Gravity	Warburg Oxygen Demand (mg.O ₂ /g/3 hrs.)
6	0.11	0.26	1.28	1.37
47	0.16	0.37	1.14	1.66
47E	0.05	0.16	1.38	0.605
87W	0.08	0.31	1.27	0.419
87	0.74	0.59	1.40	0.278
7	0.21	0.34	1.26	1.80
48	0.37	0.35	1.79	0.260
48E	0.21	0.57	1.69	0.478
88W	0.62	0.49	1.64	0.314
88	0.69	0.25	1.73	0.195
10	0.39	0.18	1.87	0.288
10E	0.44	0.20	1.99	0.155
51	0.34	0.19	1.52	0.642
51E	0.48	0.52	1.65	0.330
304	0.13	0.47	1.40	0.636
305	0.44	0.29	1.54	0.352
306	0.64	0.22	1.64	0.356
401W	0.50	0.11	1.69	0.147
401	0.37	0.16	1.42	0.698
402	0.48	0.11	1.79	0.0665
402E	0.46	0.19	1.48	0.361
403W	0.22	0.47	1.35	0.644
403	0.07	0.41	1.27	0.466
404	0.16	0.50	1.38	0.340
405	0.34	0.31	1.58	0.0901
406	0.70	0.26	1.75	0.0437
501	0.31	0.34	1.53	0.218
502	0.10	0.43	1.24	0.653
503	0.05	0.18	1.13	0.690
504	0.10	0.43	1.33	0.287
505	0.37	0.15	1.58	0.0863
506	0.17	0.31	1.50	0.146
15	0.06	0.34	1.25	2.56
16	0.42	0.16	1.65	0.0472
17	0.06	0.35	1.15	1.07
18	0.05	0.19	1.14	1.59
603	0.15	0.37	1.26	0.387
604	0.59	0.28	1.63	0.180
605	0.31	0.41	1.28	0.455
606	0.43	0.44	1.49	0.323
607	0.83	0.45	1.52	0.142
608	0.46	0.23	1.64	0.126
609	0.44	0.16	1.61	0.0484

TABLE 1 (continued)

Station	Median Grain Diameter (mm.)	Log. Sorting Coefficient	Specific Gravity	Warburg Oxygen Demand (mg.O ₂ /g/3 hrs.)
703	0.48	0.14	1.52	0.439
704	0.49	0.13	1.88	0.0259
704E	0.34	0.17	1.50	0.178
706	0.37	0.23	1.72	0.208
707	0.28	0.22	1.68	—
708	0.29	0.41	1.49	0.241
709	0.49	0.46	1.46	0.189
710	0.53	0.47	1.68	0.0937
20	0.42	0.17	1.67	0.183
20E	0.31	0.15	1.58	0.181
73W	0.42	0.20	1.46	0.242
73	0.38	0.28	1.49	0.158
709S	0.54	0.42	1.88	—
73E	0.21	0.45	1.38	—
73EE	0.27	0.50	1.41	—
21	0.51	0.15	1.77	0.128
75W	0.51	0.20	1.84	—
75	0.52	0.20	1.91	—
22	0.54	0.25	1.38	—
22E	0.45	0.24	1.54	—
801	0.51	0.15	1.85	0.0286
802	0.44	0.13	1.75	0.175
803E	0.86	0.14	1.73	0.0881
804	0.48	0.14	1.92	—
77	0.48	0.50	1.65	0.108
77E	0.05	0.27	1.38	—
75E	0.21	0.45	1.35	—
901NE	0.48	0.11	1.82	0.260
901E	0.45	0.13	1.93	0.174
901	0.10	0.39	1.29	1.25
902	0.46	0.09	1.88	0.179
901S	0.40	0.13	1.81	0.373
1001	0.48	0.11	2.22	0.0302
66	—	—	—	0.141
VK*	—	—	—	0.0107

* Marine Laboratory pier, Virginia Key, subtidal sand.

sible starting with the northernmost transect. Data on a total of 76 stations are included; at 11 of these Warburg determinations of oxygen uptake were not performed.

Figures 3, 4, and 5 show the horizontal distribution of median grain size, log sorting coefficient and oxygen uptake. Figure 3 shows

that the area is characterized by soft sediments in the mid-bay portion grading out to harder sediments along the Miami and Miami Beach shorelines where currents in dredged channels are relatively strong. Softest sediments are found along the Miami shoreline between the Miami River mouth and MacArthur Causeway in water 12 to 30 feet deep. The horizontal distribution of log sorting coefficient (Figure 4) shows that sorting is most efficient along the Miami and Miami Beach shorelines, separated by a broad band of relatively poorly sorted sediments running from north to south through mid-bay. The isoline of log 0.40, corresponding to S_n 2.5, seems to separate best the relatively well sorted from poorly sorted sediments. This result is generally consistent with the horizontal distribution of currents along the Miami and Miami Beach shorelines, where current velocities are higher than in mid-bay. However, this result is not consistent with the strong easterly-westerly currents of Government Cut where poorly sorted sediments are found at Stations 605, 606, and 607. Median diameters at these stations of 0.31, 0.43, and 0.83 mm., respectively, suggest that particles in these sediments are not readily moved despite the strong currents, with the result that secondary addition of strong currents after dredging of Government Cut has had little effect on the original character of these sediments. Results of oxygen uptake experiments are shown in Figure 5. Highest values occurred in three areas: (1) between Miami River and Venetian Causeway adjacent to the Miami shorelines; (2) at the most north-westerly stations (Stations 6 and 7); and (3) in relatively deep water off Mercy Hospital (Stations 901 and 901S). These relatively deep areas with poor bottom circulation constitute zones of major deposition of organic-rich sediments, and as such can be characterized as "degradation zones." In shallower water adjacent to these areas where vigorous tidal currents swept the bottom, generally low oxygen uptake values were obtained. Figure 5 clearly shows a second deposition area in mid-bay between Government Cut and 79th Street Causeway where oxygen uptake values were intermediate between the above. Thus, even though the mid-bay area was relatively distant from sources of sewage, deposition of organic materials was relatively high. This result is consistent with past studies on hydrography and distribution of coliforms in the area.

The above results suggest that there should be a relationship between pollution of the water (measured by MPN), grain size of the sediments (median grain diameter) and organic deposition in the

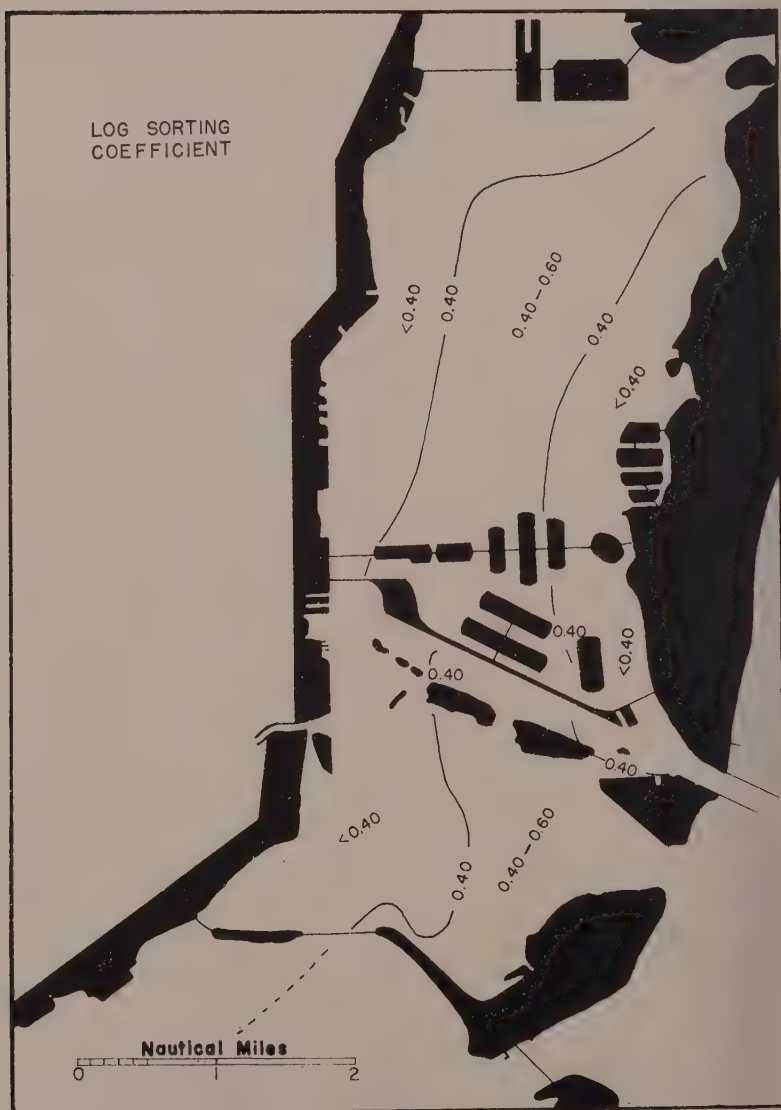


FIGURE 4. Horizontal distribution of log. sorting coefficient.

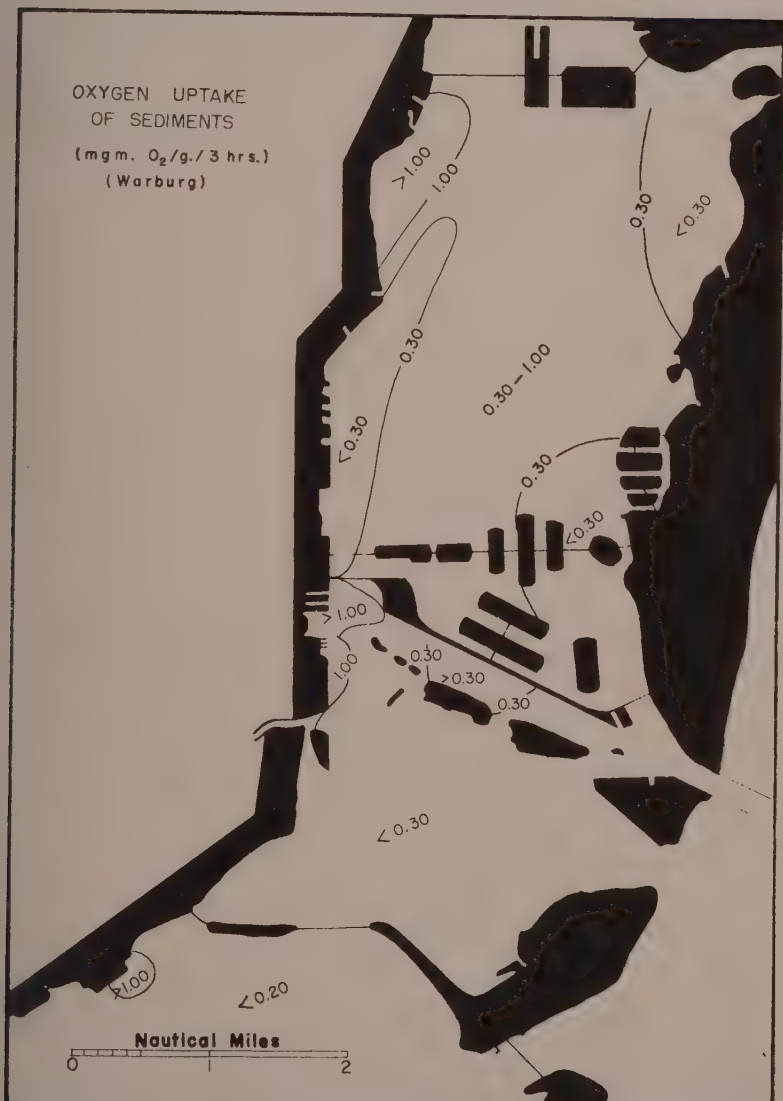


FIGURE 5. Horizontal distribution of oxygen uptake of sediments.

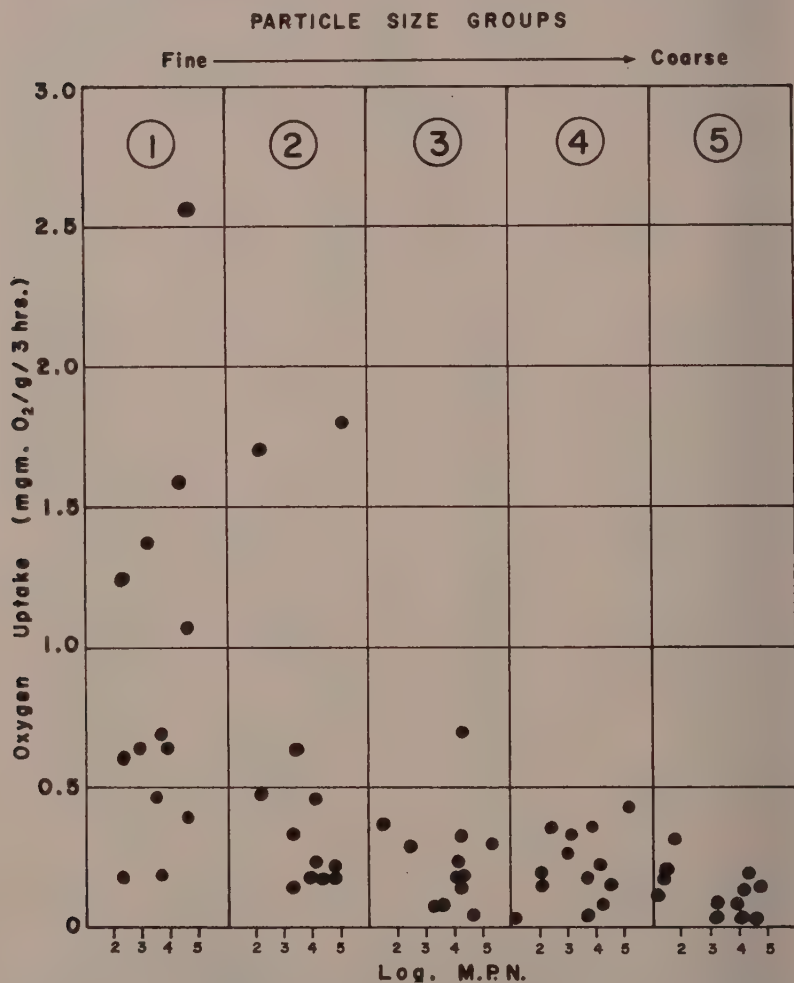


FIGURE 6. Scatter diagram of oxygen uptake of sediments against log. MPN for five groups of sediments: (1) Md. less than 0.130 mm, (2) Md. 0.131-0.340 mm, (3) Md. 0.341-0.430 mm, (4) Md. 0.431-0.490 mm, (5) Md. 0.491-0.860 mm.

sediments (oxygen uptake per gram of dry mud). In Figure 6 this relationship is shown by dividing the sediments into five equal groups within the range of particle sizes (13 stations per group), then plotting MPN at each of the stations against oxygen uptake. Group 1 at the left of the figure includes the 13 stations with lowest particle sizes (Md. less than 0.130 mm); Group 2, Md. of 0.131 to 0.340 mm; Group 3, Md. of 0.341 to 0.430 mm; Group 4, Md. of 0.431 to 0.490 mm; Group 5, Md. of 0.491 to 0.860 mm. As would be expected the highest oxygen uptake values occurred in the softest sediments, generally in response to increased MPN. In Groups 3, 4, and 5, however, the oxygen uptake bore little resemblance to the MPN scale and remained at relatively low uniform values regardless of pollution. Few stations showed high oxygen uptake values. Only 11 per cent of the stations had oxygen uptake values greater than 0.7 mgm O_2 per gram of dry mud, and only 22 per cent had uptake values in excess of 0.5 mgm O_2 . Thus, even though the pollution level is very high, organic materials are incorporated in the sediments only under hydrographic conditions which permit deposition of the organic load.

BENTHIC MACRO-ORGANISMS

By means of the Petersen grab the quantitative distribution of benthic macro-organisms has been determined in order to show the relationship of sewage to bottom life in this estuary. A systematic list of the common species is shown in Table 2. The relatively limited sampling of 16 stations in 1954 (McNulty, 1955) and of 11 stations in 1955 on an east-west transect across a sharp pollution gradient (McNulty, 1956) showed evidence of orientation of bottom life to pollution. Equally clear was evidence that nature of sediment, hydrography, depth, turbidity and other variables masked or completely disguised the effects of sewage. For example, the ophiuran *Ophionephrys limicola* was present in early sampling at Station 16 located in a shallow area which juts into and is surrounded on three sides by a highly polluted degradation area essentially devoid of life. A listing of high pollution tolerant species would surely have included this animal, erroneously, unless its true distribution in the area and its relationship to nature of sediment could be determined. Consequently, the number of stations was increased in July and August, 1956, to 65 (plus an additional 11 stations for attached vegetation alone). Table 3 lists results of this survey.

TABLE 2

SYSTEMATIC LIST OF MAJOR SPECIES OF BENTHIC
MACRO-ORGANISMS COLLECTED FROM NORTHERN BISCAYNE BAY

Division Spermatophyta (Seed Plants) (Identifier, McNulty)	
Class Monocotyledons	
<i>Cymodocea manatorum</i> Ascherson	<i>Halophila baillonis</i> Ascherson
<i>Diplanthera wrightii</i> (Ascherson) Ascherson	<i>Thalassia testudinum</i> König
Division Phycophyta (Algae) (Identifier, McNulty, aided by R. H. Williams)	
Class Chlorophyceae	
<i>Bryopsis hypnoides</i> Lamouroux	<i>Cladophora gracilis</i> (Griffiths) Kuetzing
<i>Caulerpa crassifolia</i> (C. Agardh) J. Agardh	<i>Enteromorpha prolifera</i> (O. F. Muller) J. Agardh
<i>Caulerpa prolifera</i> (Foerskal) Lamouroux	<i>Halimeda tridens</i> (Ellis and Solander) Lamouroux
<i>Caulerpa sertularioides</i> (Gmelin) Howe	<i>Udotea spinulosa</i> Howe
<i>Chaetomorpha brachygonia</i> Harvey	<i>Ulva lactuca</i> Linnaeus
Class Rhodophyceae	
<i>Acanthophora specifera</i> (Vahl) Borgesen	<i>Gracilaria blodgettii</i> Harvey
<i>Agardhiella tenera</i> (J. Agardh) Schmitz	<i>Hypnea cervicornis</i> J. Agardh
<i>Ceramium tenuissimum</i> (Lyngbye) J. Agardh	<i>Hypnea cornuta</i> (Lamouroux) J. Agardh
<i>Cryptonemia luxurians</i> (Mertens) J. Agardh	<i>Laurencia obtusa</i> (Hudson) Lamouroux
Class Phaeophyceae	
<i>Dictyota dichotoma</i> (Hudson) Lamouroux	<i>Polysiphonia subtilissima</i> Montagne
Class Xanthophyceae	
<i>Vaucheria</i> sp.	<i>Wrangelia bicuspidata</i> Borgesen
Phylum Coelenterata	
Class Anthozoa	
anemone, unidentified	
Phylum Annelida	
Class Polychaeta (Identifier, McNulty)	
<i>Ammotrypane aulogaster</i> H. Rathke	<i>Owenia fusiformis</i> delle Chiaje
<i>Branchiomma nigromaculata</i> (Baird)	<i>Pista cristata</i> (Muller)
<i>Cistenides gouldii</i> Verrill	<i>Pista</i> sp.
<i>Diopatra cuprea</i> (Bosc)	<i>Polydora websteri</i> Hartman
<i>Glycera</i> sp.	<i>Semiodera roberti</i> Hartman
<i>Lumbrineris</i> sp.	<i>Spiochaetopterus oculatus</i> Webster
<i>Maldane sarsi</i> Malmgren	<i>Sthenelais</i> sp.
<i>Naineris setosa</i> (Verrill)	<i>Terebellides stroemi</i> Sars
<i>Onuphis magna</i> (Andrews)	
Phylum Sipunculoidea	
sipunculid, unidentified	
Phylum Echinodermata (Identifier, McNulty, aided by L. P. Thomas)	
Class Ophiuroidea	

TABLE 2 (Continued)

<i>Amphioplus abditus</i> (Verrill)	<i>Ophionephthys limicola</i> Lütken
<i>Amphioplus coniotodes</i> H. L. Clark	<i>Amphiodia pulchella</i> (Lyman)
Phylum Mollusca (Identifier, McNulty, aided by R. C. Work)	
Class Pelecypoda	
<i>Atrina rigida</i> (Solander)	<i>Macoma</i> sp.
<i>Atrina serrata</i> (Sowerby)	<i>Macra fragilis</i> Gmelin
<i>Botula castanea</i> (Say)	<i>Modiolus americanus</i> (Leach)
<i>Cardita floridana</i> (Conrad)	<i>Modiolus papyria</i> (Conrad)
<i>Chione cancellata</i> (Linnaeus)	<i>Tagelus divisus</i> (Spengler)
<i>Codakia orbicularis</i> (Linnaeus)	<i>Tellina alternata</i> Say
<i>Cumingia tellinoides</i> (Conrad)	<i>Tellina similis</i> Sowerby
<i>Cyclinella tenuis</i> (Récluz)	<i>Tellina versicolor</i> Cozzens
<i>Dosinia elegans</i> (Conrad)	<i>Tellina</i> sp.
<i>Laevicardium murtoni</i> (Conrad)	<i>Trachycardium egmontianum</i>
<i>Lima pellucida</i> C. B. Adams	(Shuttleworth)
<i>Lucina multilineata</i>	<i>Trachycardium muricatum</i>
(Tuomey & Holmes)	(Linnaeus)
<i>Phacoides muricatus</i> (Spengler)	
Class Gastropoda	
<i>Anachis avara</i> (Say)	<i>Mitrella lunata</i> Say
<i>Conus floridanus</i> Gabb	<i>Nassarius vibex</i> (Say)
<i>Conus stearnsii</i> Conrad	<i>Neritina virginea</i> (Linnaeus)
<i>Bulla occidentalis</i> A. Adams	<i>Turbo castaneus</i> Gmelin
<i>Haminoea antillarum guadelupensis</i>	
Sowerby	
Phylum Arthropoda	
Class Crustacea	
Order Tanaidacea	
tanaidacean, unidentified	
Order Isopoda	
isopod, unidentified	
Order Amphipoda (Identifier, D. G. Ahearn, checked by C. R. Shoemaker)	
<i>Corophium acherusicum</i> Costa	<i>Grubia filosa</i> (Savigny)
	<i>Grubia</i> sp.
Order Decapoda (Identifier, McNulty)	
<i>Eucratopsis crassimanus</i> (Dana)	spider crabs, unidentified
other grapsoid crabs, unidentified	shrimps, unidentified
hermit crabs, unidentified	
Phylum Chordata	
Subphylum Tunicata	
ascidians, unidentified	

The data have been analyzed in two ways: (1) by applying the principles of Thorson's method of characterizing bottom communities (Thorson, 1957; 477), and (2) by examining the relationship of selected individual species to pollution (MPN), oxidizable organic of sediments (mgm O₂/g/3 hours in Warburg respirometer), and particle size (median grain diameter).

TABLE 3

SPECIES AND QUANTITIES OF PLANTS AND ANIMALS TAKEN IN THREE PETERSEN GRAB SAMPLES (TOTAL AREA SAMPLED PER STATION EQUALS 0.222 m²) DURING JULY AND AUGUST, 1956, IN BISCAYNE BAY, FLORIDA. QUANTITIES OF PLANTS ARE IN MILLILITERS DISPLACEMENT VOLUME; ANIMAL QUANTITIES ARE IN NUMBERS OF INDIVIDUALS.

Species	Station Number											
	6	47	47E	87W	87	7	48	48E	88W	88	10	10E
51	51	51	51	51	51	51	51	51	51	51	51	51
306	306	306	306	306	306	306	306	306	306	306	306	306
Marine Spermatophytes												
<i>Halophila baillonis</i>			6	10						40		18
<i>Diplanthera wrightii</i>							130	210	290			16
<i>Cymodocea manatorum</i>	38											6
<i>Thalassia testudinum</i>									30	135		20
Phaeophyceae		4					tr ¹	tr	tr	tr	tr	2
<i>Dictyota dichotoma</i>												
Rhodophyceae												
<i>Agardhiella tenera</i>	5	tr				tr	tr			24	12	4
<i>Gracilaria blodgettii</i>	tr					tr				tr	5	tr
<i>Hypnea cervicornis</i>						tr	tr			tr	4	tr
<i>Acanthophora speciosa</i>	6			7			tr	tr		tr	tr	8
<i>Laurencia obtusa</i>												
Phylum Annelida												
Class Polychaeta												
<i>Diopatra cuprea</i>	2	3				4	5		1	3	6	22
<i>Pista cristata</i>	1			4			16	4	5	1	2	2
<i>Glycera</i> sp.	1	2	2	3		2			1	1	2	2
<i>Spiochaetopterus oculatus</i>	2					15					4	4
<i>Terebellides stroemi</i>			14					2			15	4
<i>Cistenides gouldii</i>	1										3	3
<i>Branchiomma nigromaculata</i>										5		1
<i>Semiodon roberti</i>							1	1				2
<i>Lumbrineris</i> sp.				2								2
<i>Sthenelais</i> sp.	2			1		2	2	2			4	12
polychaetes, unidentified											11	45
Total Polychaetes	9	5	16	10	0	23	24	9	7	2	9	—

TABLE 3 (Continued)

Species	Station Number																
	6	47	47E	87W	87	7	48	48E	88W	88	10	10E	51	51E	304	305	306
Phylum Arthropoda																	
Class Crustacea																	
Order Isopoda										1							
unidentified isopod																	
Order Amphipoda																	
<i>Grubia filosa</i>												2					
Order Stomatopoda																	
unidentified stomatopod										1							
Order Decapoda																	
<i>Eucratopsis crassimanus</i>		2													1		
unident. grapsoid crab								2									
unident. hermit crabs		1					1		1	2							
unident. spider crab										1							
Total crustaceans:	—	3	—	—	—	—	1	2	3	3	—	—	2	—	—	1	—

Phylum Mollusca																	
Class Pelecypoda																	
<i>Tellina versicolor</i>	5	3		2		5	3	3	4		2		4	8	3	12	
<i>Tellina alternata</i>						1	1				1				2		
<i>Chione cancellata</i>							4	8	4	3					1	10	9
<i>Tagelus divinus</i>	2	3		6		6	3	2		13			19	2			
<i>Laevicardium mortoni</i>																	
<i>Tellina</i> sp.		1				3											1
<i>Cardita floridana</i>		1															
<i>Atrina rigida</i>		1															
<i>Macoma</i> sp.		1		7				1									
<i>Cyclinella tenuis</i>				3						1				3	1		

(Continued)

[illegible]

TABLE 3 (Continued)

Species	Station Number														
	401W	401	402	402E	403W	403	404	405	406	501	502	503	504	505	506
Marine Spermatophytes															
<i>Halophila baillonis</i>			5	26	4			18	12					tr	13
Chlorophyceae															
<i>Caulerpa prolifera</i>		4	3	tr					tr						
<i>Caulerpa crassifolia</i>				tr											
<i>Ulva lactuca</i>			tr	tr											
<i>Enteromorpha prolifera</i>				tr											
<i>Cladophora gracilis</i>				tr											
Rhodophyceae															
<i>Agardhiella tenera</i>		8	3	tr					tr						
<i>Hypnea cervicornis</i>	tr	5		tr									tr	8	
<i>Acanthophora speciosa</i>		1	tr	tr				tr	tr				tr	tr	
<i>Laurencia obtusa</i>		tr						tr					tr		
<i>Polysiphonia subtilissima</i>		tr	tr												
<i>Cryptonemia luxuriata</i>															
<i>Wrangelia bicuspidata</i>				tr					tr						
Phaeophyceae													tr		
<i>Dictyota dichotoma</i>		5	5												
Xanthophyceae															
<i>Vaucheria</i> sp.											86				
Phylum Coelenterata															
Class Anthozoa															
unidentified anemones	1									2					
Phylum Annelida															
Class Polychaeta															
<i>Diopatra cuprea</i>		5			3					3					
<i>Pista cristata</i>		2	3												
<i>Glycera</i> sp.	15	9	9	3	1		1	8	8	8	5		1	3	
<i>Terebellides stroemi</i>				1	1	2	1	3	11	7	2	2	2	12	5
<i>Cistenides gouldii</i>		3	2										7		

(Continued)

TABLE 3 (Continued)

TABLE 3

Species	Station Number									
	401W	401	402	402E	403W	403	404	405	406	
<i>Grubia</i> sp.				2						
Order Decapoda										2
<i>Eucratoropsis crassimanus</i>										
unid. grapsoid crabs	1		1		2		1	1	1	1
unid. caridean shrimps										
Total crustaceans	0	202	4	18	2	0	0	1	0	3
										12
										0
Total amphipods and tan-aidaceans	201	3	14	0	0	0	0	0	2	12
										0
										4
Phylum Mollusca										
Class Pelecypoda										
<i>Tellina versicolor</i>	32	28	38	8	4	4	4	14	3	27
<i>Tellina alternata</i>					6					11
<i>Chione cancellata</i>	21	38	20							22
<i>Tagelus divisus</i>	1	18	10						3	32
<i>Laevicardium mortoni</i>	2	2	1						43	40
<i>Cumingia tellinoides</i>	1	8	8							2
<i>Lima pellucida</i>	1		1						3	
<i>Macoma</i> sp.	3									
<i>Trachycardium egmontianum</i>	1									
<i>Modiolus papyria</i>	1									
<i>Haminoea antillarum guadelupensis</i>	2	3	1						3	
<i>Dosinia elegans</i>		1	1							
<i>Botula castanea</i>		2								
<i>Trachycardium egmontianum</i>		1								
<i>Lucina multilineata</i>										
										11

(Continued)

TABLE 3 (Continued)

Species	Station Number															
	401W	401	402	402E	403W	403	404	405	406	501	502	503	504	505	506	
<i>Cardita floridana</i>				1									1		1	
<i>Cyclinella tenuis</i>													1			
unidentified pelecypods																
Total pelecypods:	0	65	101	82	8	10	4	14	49	116	20	7	37	114	37	
Class Gastropoda																
<i>Nassarius vibex</i>	1	5	8	1	1					4	4		1		3	
<i>Haminoea antillarum guadelupensis</i>		2	3	1						3						
<i>Bulla occidentalis</i>			8							3	2					
<i>Anachis avara</i>										3			1			
<i>Mitrella lunata</i>																
Total gastropods:	1	7	19	2	1					10	6		2		3	
Phylum Echinodermata																
Class Ophiuroidea																
<i>Amphioplus abditus</i>			1		1				9	1			1	8		
<i>Amphioplus constrictus</i>					1								3			
<i>Ophionephthys limicola</i>					5	1	1	1		1		2	1		3	
<i>Amphipholis gracillima</i>								1								
<i>Amphiodia pulchella</i>									4							
Phylum Chordata																
Subphylum Tunicata																
unidentified ascidians	14		7				2			2			3			

TABLE 3 (Continued)

Species	15	16	17	18	603	604	605	606	608	609	703	704	704E	706	707	708	709	710
Marine Spermatophytes																		
<i>Halophila baillonis</i>																		
<i>Diplanthera wrightii</i>					12	tr	28	25	tr	210	180			66	38	tr		85
unidentified spermatophyte																		
Chlorophyceae																		
<i>Caulerpa prolifera</i>	2										3	tr						tr
<i>Caulerpa crassifolia</i>														tr				
<i>Ulva lactuca</i>			tr															
<i>Enteromorpha prolifera</i>												tr						
<i>Cladophora gracilis</i>	tr											tr						
<i>Chaetomorpha brachygona</i>					tr	tr						tr				tr		
<i>Bryopsis hypnoides</i>	1																	
<i>Caulerpa sertularioides</i>																		tr
<i>Udotea spinulosa</i>																		5
<i>Halimeda tridens</i>																		8
Rhodophyceae																		
<i>Agardhiella tenera</i>																		
<i>Hypnea cervicornis</i>	8																	
<i>Acanthophora speciosa</i>	4		tr											tr				tr
<i>Laurencia obtusa</i>																		
<i>Polysiphonia subtilissima</i>	2																	
<i>Wrangelia bicuspidata</i>																		
<i>Gracilaria blodgettii</i>	8																	
<i>Ceramium tenuissimum</i>	tr																	
<i>Hypnea cornuta</i>																		
<i>Laurencia intricata</i>																		
Xanthophyceae																		
<i>Vaucheria</i> sp.																		
Phylum Annelida																		
Class Polychaeta																		

(Continued)

TABLE 3 (Continued)

[illegible]

TABLE 3 (Continued)

Species	15	16	17	18	603	604	605	606	607	608	609	703	704	704E	706	707	708	709	710
Order Decapoda																			
<i>Eucratopsis crassimanus</i>									1	2							1		
unident. grapsoid crabs															2				
unident. hermit crabs	2							1			1								
unident. spider crabs															5	2			
unident. snapping shrimps							1	1	6	1								1	
other unident. carideans															1			1	
Total crustaceans	8				6	1	3	7	1	2	3	51			8	2	1	2	
Total amphipods and tanaiaceans																			
	6				6		1	1		1		51							
Phylum Mollusca																			
Class Pelecypoda																			
<i>Tellina versicolor</i>	2			1	2	12	15	21		2		7	1	17			3	1	
<i>Tellina alternata</i>								2									1		
<i>Chione cancellata</i>	62			3	3	4	4	3		7	4	14	3	53	3		1		
<i>Tagelus divisus</i>				3		3	1	19			1	6	13	10	1		1		
<i>Laevicardium mortoni</i>	4				2	2	2						1		1				
<i>Cumingia tellinoides</i>					1		1												2
<i>Tellina</i> sp.												6			1				
<i>Trachycardium muricatum</i>									2						2				
<i>Atrina serrata</i>								1											
<i>Trachycardium egmontianum</i>																			1
<i>Macoma</i> sp.	1											1		1					
<i>Botula castanea</i>															3				
<i>Macra fragilis</i>															3				

(Continued)

TABLE 3 (Continued)

Species	Station Number																		
	15	16	17	18	603	604	605	606	607	608	609	703	704	704E	706	707	708	709	710
<i>Dosinia elegans</i>		1													3				
<i>Cardita floridana</i>															3				1
<i>Lima pelucida</i>															2				8
<i>Tellina similis</i>																			2
<i>Lucina nassula</i>		3																	
<i>Lucina multilineata</i>																			
Total pelecypods:	0	73	0	4	5	22	24	45	3	9	5	20	16	34	71	13	7	1	14
Class Gastropoda																			
<i>Nassarius vibex</i>		16										16	34		17	1			
<i>Haminoea antillarum</i>													1		3				
<i>guadelupensis</i>		2								1									
<i>Bulla occidentalis</i>		2											11						1
<i>Neritina virginea</i>																			
<i>Turbo castaneus</i>																			
Total gastropods:		20									1	16	46		20	1			1
Phylum Echinodermata																			
Class Ophiuroidea																			
<i>Amphiopterus abditus</i>						1	1									1	2	3	8
<i>Amphiopterus coniotodes</i>							1						3				1	2	
<i>Ophionephthys limicola</i>		2		1	1	1	3	2	1					2			1	1	1
<i>Amphiodia pulchella</i>																1			1
Phylum Chordata																			
Subphylum Tunicata																			
unidentified ascidians	1				2					6					3				

TABLE 3 (Continued)

Species	Station Number									
	20	20E	73W	73	801	802	803E	77	901NE	901S
Marine Spermatophytes										
<i>Halophila baillonis</i>							tr			
<i>Diplanthera wrightii</i>							30			
<i>Thalassia testudinum</i>							tr			
unidentified spermatophyte								54		
Chlorophyceae										
<i>Ulva lactuca</i>										
<i>Acetabularia crenulata</i>						80				
Rhodophyceae										
<i>Acanthophora speciosa</i>						55				
<i>Laurencia obtusa</i>										
Phaeophyceae										
<i>Dictyota dichotoma</i>						60				
Xanthophyceae										
<i>Vaucheria</i> sp.										
Phylum Annelida										
Class Polychaeta										
<i>Pista cristata</i>										
<i>Pista</i> sp.										
<i>Glycera</i> sp.										
<i>Terebellides stroemi</i>										
<i>Branchiomma nigromaculata</i>										
<i>Semiodera roberti</i>										
<i>Lumbrineris</i> sp.										
<i>Sthenelais</i> sp.										
<i>Ammotrypane aulogaster</i>										
<i>Owenia fusiformis</i>										
<i>Onuphis magna</i>										
unidentified polychaetes										
Total polychaetes	18	11	16	7	11	8	11	15	4	6

(Continued)

TABLE 3 (Continued)

Species	Station Number										
	20	20E	73W	73	801	802	803E	77	901NE	901NNE	901S
<i>Ophionephthys limicola</i>	1	1						1			2
<i>Amphiodia pulchella</i>									1		
Phylum Chordata											
Subphylum Tunicata											
unidentified ascideans					7						

TABLE 3

Species	Station Number						
	709S	73E	73EE	21	75W	75	22E
Marine Spermatophytes							
<i>Halophila baillonis</i>					tr	tr	
<i>Diplanthera wrightii</i>							15
<i>Thalassia testudinum</i>			400				
Chlorophyceae							
<i>Ulva lactuca</i>							
<i>Caulerpa sertularioides</i>		tr					
Rhodophyceae							10
<i>Acanthophora</i> sp.	tr						
Phaeophyceae							
<i>Dictyota cervicornis</i>			tr				

! The notation "tr" means "trace."

Thorson divides characterizing species of bottom communities into four groups: (1) characterizing species of the 1st order, which include conspicuous animals found only in one definite community and in some quantity (occurring in at least 50 per cent of the standard unit samples and making at least 5 per cent of the total living weight per standard unit); (2) characterizing species of the 2nd order, which include conspicuous animals found only in certain parts within one definite community and in some quantity (occurring in at least 50 per cent of the standard unit samples and making at least 5 per cent of the total living weight per standard unit); (3) characterizing species of the 3rd order, which include animals found in such large quantities (occurring in at least 70 per cent of the standard unit samples and making up at least 10 per cent of the total living weight per standard unit) that by their mere appearance they influence one's notion of the community, but which may also be found in quantities in other communities; (4) associated animals (= influents), which include all other more common animals of a community (occurring in at least 25 per cent of the standard unit samples and making up at least 2 per cent of the total living weight of the standard unit) which are not of such great importance for the characterization of the community. The above definitions are consistent with the concept of biotic communities generally (Elton, 1946, p. 15; Allee *et al.*, 1950, p. 442).

The occurrence of fixed vegetation at most stations in northern Biscayne Bay adds an additional complexity which Thorson did not need to consider. It is an essential element of the ecology of the bay and has been treated as such in the analysis. On the basis of the fixed vegetation, the study area can be divided into two major zones: (1) a red algae zone in which various species of Rhodophyceae predominate, and (2) a spermatophyte zone in which *Halophila baillonis* and *Diplanthera wrightii* predominate. The red algae zone was found along the Miami shoreline easterly to roughly the Intracoastal Waterway, while the area between the waterway and Miami Beach, Fisher Island and Virginia Key was characterized at most stations by spermatophytes. The horizontal distribution of these two zones is shown in Figure 7. The figure also indicates predominant species of spermatophytes in areas of abundant growth (abundance was measured in the field by displacement volumes per 0.222 m^2). *Halophila* generally, but not always, penetrated more heavily polluted areas than *Diplanthera*, and unusual abundance of the former generally occurred



FIGURE 7. Horizontal zonation of fixed vegetation.

along fringes of highly polluted areas.

These facts led to the search for animals with similar zonation. It was found that the tubiculous errantiate polychaete *Diopatra cuprea* was consistently associated with either or both the red algae *Gracilaria blodgettii* and *Agardhiella tenera*, and that these species in combination came closest to qualifying as characterizing species of the 1st order of a community located mainly along the Miami shoreline, west of the Intracoastal Waterway, in areas of heaviest pollution. Two algal species instead of one were selected because: (1) the distribution of the two overlapped completely in the area north of the Venetian Causeway; (2) of the 13 stations where the above association was found, the polychaete *D. cuprea* was concurrent with *G. blodgettii* alone at 5 stations, concurrent with *A. tenera* alone at 5 stations, and concurrent with both at 3 stations, indicating no statistical advantage in favor of the choice of either one; (3) of the 16 stations where *D. cuprea* occurred throughout the area, it was concurrent with either or both of the above algal species at 13 stations (81 per cent), but concurrent with either of the algal species alone at only 8 stations each (50 per cent); and (4) of the 3 stations at which *D. cuprea* was found unassociated with either or both of the algal species, only one station was located west of the Intracoastal Waterway. There remains the possibility that more complete sampling would have shown a clear relationship of *D. cuprea* to one or the other of the algal species. Since *G. blodgettii* penetrated areas of lower salinity than *A. tenera*, it seems most reasonable to speculate that statistical evidence would favor choice of *G. blodgettii* after further sampling.

The horizontal distribution of the above association was used to define community boundaries, shown in Figure 8. The selection of other species in the community was based on the distribution of 1st order species. A list of all species occurring in this (red algal zone) community follows.

First Order species: (*G. blodgettii* and/or *A. tenera*) plus *D. cuprea*.

Second Order species: *Ulva lactuca*, *Cistenides gouldii*, *Spiochaetopterus oculatus*.

Third Order species: *Acanthophora specifica*, *Glycera* sp., *Tellina versicolor*, and *Nassarius vibex*.

Associated species: *Laurencia obtusa*, *Dictyota dichotoma*, *Hypnea cervicornis*, *Pista cristata*, *Branchiommia nigromaculata*, *Chione can-*

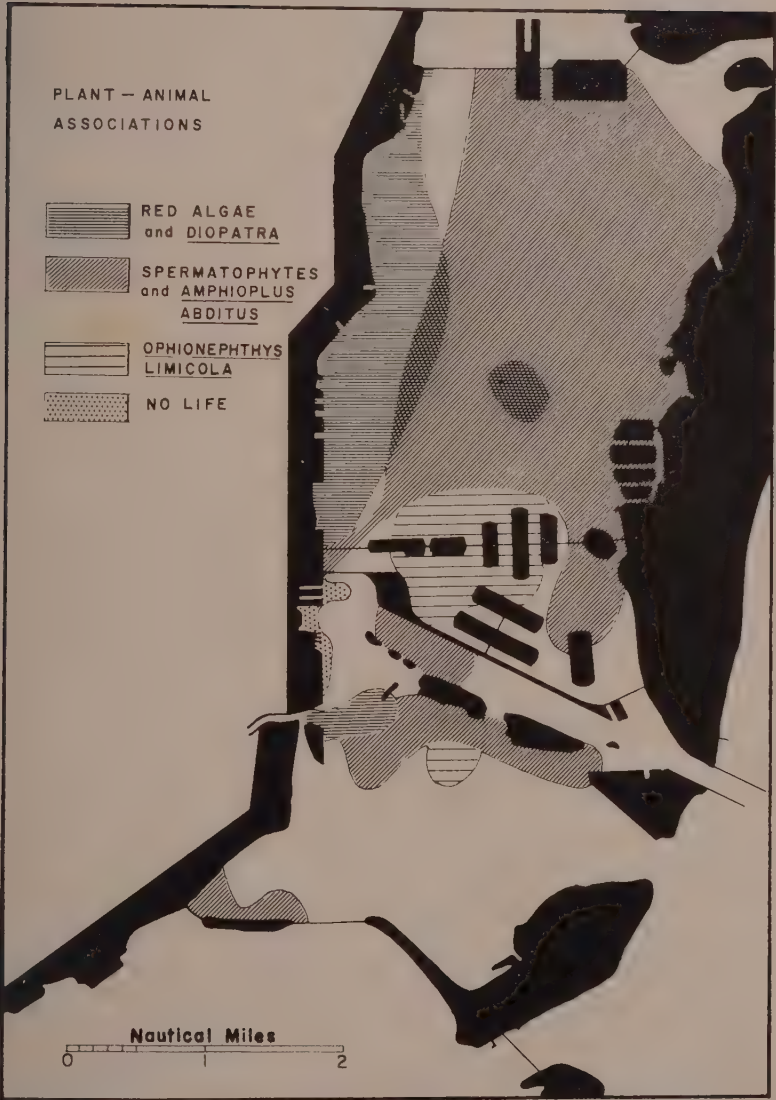


FIGURE 8. Horizontal distribution of four benthic biological zones (diagrammatic).

cellata, *Tagelus divisus*, *Laevicardium mortoni*, *Haminoea antillarum guadelupensis*.

The search for an animal with similar distribution to that of the spermatophytes *H. baillonis* and *D. wrightii* disclosed that the ophiuran *Amphioplus abditus* was associated consistently with either or both of them. The ophiuran occurred alone with *H. baillonis* at 16 stations, with both spermatophytes at 3 stations and with *D. wrightii* alone at 4 stations. As already mentioned, *H. baillonis* generally penetrated into more polluted water than did *D. wrightii*. It would be incorrect to select one or the other of the spermatophytes as first order characterizing species because of the close similarity between the horizontal distribution of the ophiuran and all spermatophytes together. The spermatophytes had a wider distribution than the ophiuran, the concurrence of spermatophytes with *A. abditus* being 69 per cent. However, *A. abditus* was concurrent with the spermatophytes in 85 per cent of its range and in such a manner, geographically, as to define community boundaries as distinct from and adjacent to the red algal zone community. The geographical boundaries of this association are shown also in Figure 8. The association was found primarily adjacent to highly polluted areas in medium to low pollution (of which more below). A listing of all species found in this (spermatophyte zone) community follows:

First Order species: *H. baillonis* and/or *D. wrightii* plus *A. abditus*.

Second Order species: None.

Third Order species: *T. versicolor*, *C. cancellata* and *T. divisus*.

Associated species: *A. specifica*, *P. cristata*, *Glycera* sp., *Terebellides stroemi*, *Lumbrineris* sp., *Sthenelais boa*, *N. vibex* and *Ophionephthys limicola*.

Two additional zones not mentioned above were also found. One of these, a zone of essentially no life, was found in the degradation area at three stations between Miami River and Venetian Causeway along the Miami shoreline (Stations 15, 17, and 18) where pollution was very high. The other zone, found mainly in mid-bay near MacArthur and Venetian Causeways, was characterized by little or no fixed vegetation and by presence of the ophiuran *O. limicola*. Since this species occurred as an associated animal in the spermatophyte zone, it could not qualify as a characterizing species of the 1st order here, although it approached this status more closely than any other species. It occurred at a higher percentage of stations here than in the

other zones (58 per cent compared with 36 per cent in the spermatophyte zone and 13 per cent in the red algae zone), unlike all other species except *Terebellides stroemi* and to a lesser extent *Lumbrineris* sp., both of which showed slightly higher percentage occurrences here than in the other zones. The most definite possible

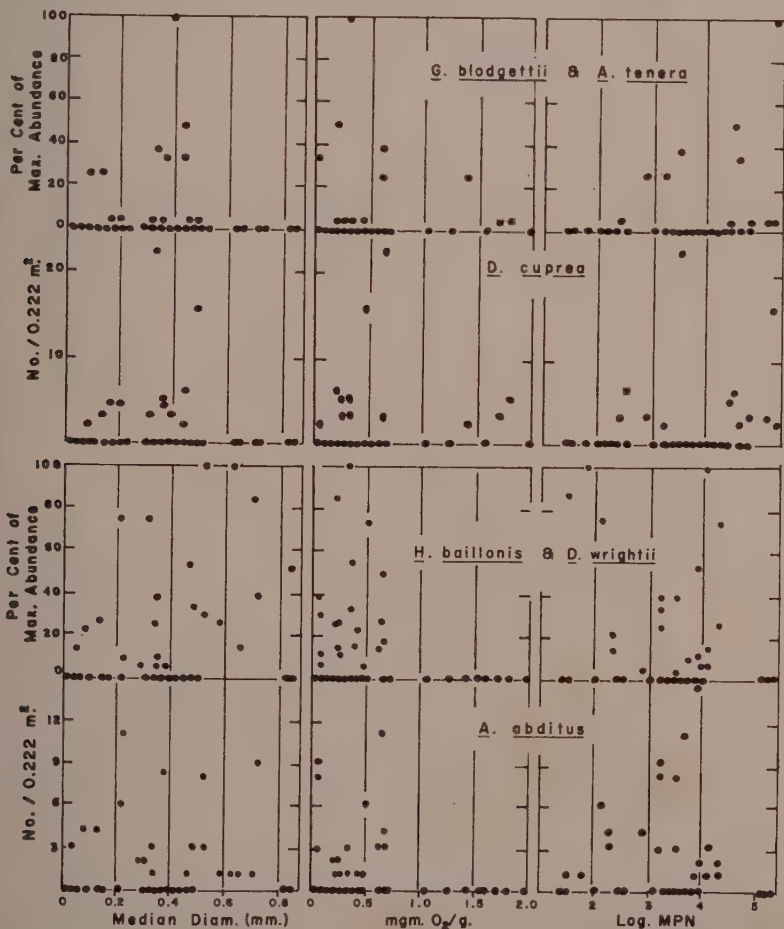


FIGURE 9. Scatter diagrams of the abundance of 1st order characterizing species of both red algal and spermatophyte communities against median grain diameter, oxygen uptake of sediments, and log. MPN.

conclusion is that this is an anomalous zone in which community structure is ill-defined, characterized mainly by the ophiuran *O. limicola* and to some extent by the polychaetes *T. stroemi* and *Lumbrineris* sp. The horizontal distribution of this and the degradation zones are shown in Figure 8.

Doudoroff maintains that when proposing and describing biological indices, one should state specifically what it is that each is believed to indicate, carefully avoiding such general, vague, or abstract terms as "pollution" and "stream health" which may be variously understood (Doudoroff & Warren, 1957).

In this study, relationships of the most important species to particle size and oxygen demand of the sediments, and to MPN of the water, are known. The data permit direct comparisons of occurrence and abundance of selected organisms with these environmental factors, as done in Figure 9, with the results summarized below.

<i>Environmental Factor</i>	<i>Relationship of 1st Order species</i>	
	<i>Red Algae Zone</i>	<i>Spermatophyte Zone</i>
Sediment Particle Size	In very fine to medium sand	In silt to coarse sand
Oxygen Uptake of Sediment	In very low to high uptake sediments	In very low to medium uptake sediments
Pollution (MPN)	In medium to very high pollution (2.4 - 5.3 log MPN)	In low to fairly high pollution (1.8 - 4.3 log MPN)

BIOLOGICAL INDICATORS OF POLLUTION

As shown in Figure 9, the 1st order species of neither group were in themselves particularly useful indicators of pollution as measured by MPN. Searching further, it was found that certain 2nd order and associated species of the red algae zone community occurred only within fairly restricted MPN ranges. Such a result is to be expected since by definition the 2nd order characterizing species are those which are found only in certain parts within one definite community, and the associated species (while occurring also outside the community) are conspicuous because they occur in at least 25 per cent of the standard unit samples within one definite community. Graphing the MPN limits of distribution of the 2nd order and associated species of the red algae zone community, the data indicated an orderly ar-

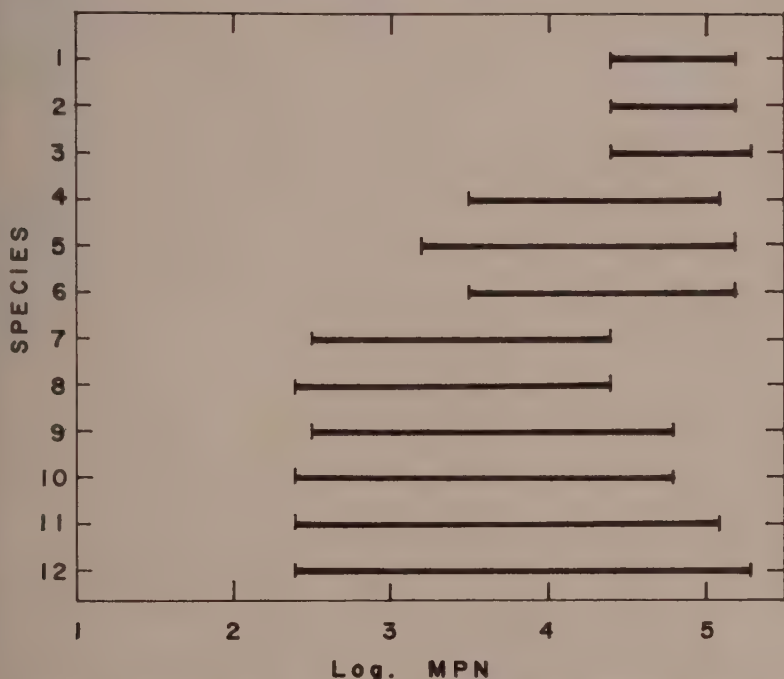


FIGURE 10. Ranges of MPN within which 2nd order and associated species of the red algal association were found. Numbers refer to the following species: 1. *Ulva lactuca*, 2. *Branchiomma nigromaculata*, 3. *Laurencia obtusa*, 4. *Spiochaetopterus oculatus*, 5. *Cistenides gouldii*, 6. *Hypnea cervicornis*, 7. *Pista cristata*, 8. *Laevicardium mortoni*, 9. *Chione cancellata*, 10. *Haminoea antillarum*, 11. *Tagelus divisus*, 12. *Dictyota dichotoma*.

range of species by their occurrence within fairly restricted ranges of MPN, as shown in Figure 10. Because these species either singly or in combination occur within different MPN ranges, their distribution within the red algae zone community may indicate pollution in the manner listed below.

1. Log MPN 2.5 - 3.2 if any or all of species 7 - 12 are present, but species 1 - 6 are absent.

2. Log MPN 3.2 - 4.4 if any or all species 5 - 8 are present, but species 1 - 4 are absent.

3. Log MPN 4.4 - 5.3 if any or all species 1 - 4 are present, but species 7 and 8 are absent.

In the spermatophyte zone community there were no 2nd order characterizing species. The distribution of associated species showed no clear orientation to pollution (except by abundance, discussed below). Since this community was located in medium to low pollution, it seems likely that with increasing dilution of sewage, other factors assume relatively greater importance, and the orientation of benthic life to sewage is less pronounced than in areas of primarily high pollution. The only general conclusion is that this community was not found in areas with greater than 4.3 log MPN.

The remaining two zones (zone of no life and zone of no attached vegetation but with the ophiuran *O. limicola*) had definite indicator

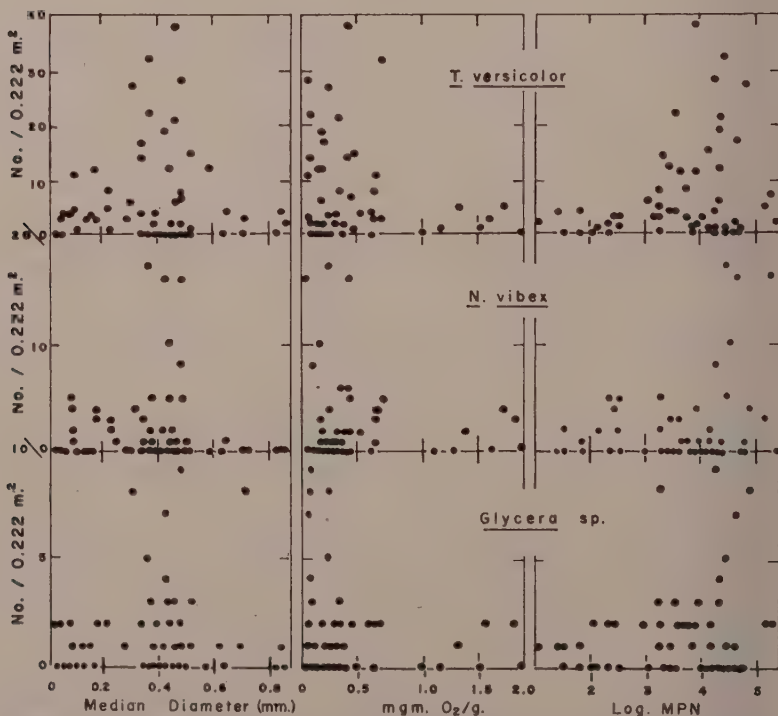


FIGURE 11. Scatter diagrams of the abundance of 3rd order characterizing species of the red algal association against median grain diameter, oxygen uptake of sediments, and log. MPN.

value. The zone of no life occurred only where log MPN was 4.4 or greater. The *O. limicola* zone (in mid-bay where it was surrounded by areas with fixed vegetation) occurred only in the range 3.3 - 4.7 log MPN.

The above indices are qualitative only. It has been found that the quantities of certain species are potentially useful as well. Those species of greatest quantitative value are the 3rd order species of both communities (those occurring in at least 70 per cent of the standard unit samples in one or both communities, and found in quantity outside each community). It has been found that unusual abundance of these species occurred within fairly restricted ranges of MPN. Rather than attempt to define the term "unusual abundance," a series of scatter diagrams of the 3rd order species of both communities has been prepared, in order to show the range of tolerances and orientation of these species to the three environmental factors: median diameter of sediments, oxygen uptake of sediments, and MPN. Figure 11 indicates that the scavenging gastropod *Nassarius vibex* was abruptly more abundant in areas with log MPN greater than 4.2, that the selective deposit feeder *Tellina versicolor* was unusually abundant between about 3.4-4.9 log MPN, and that the errantiate polychaete *Glycera* sp. showed high abundance between about 3.2 and 4.9 log MPN. One additional 3rd order species of this zone, the red alga *Acanthophora specifica*, not shown in the figure, was unusually abundant (abundance greater than 50 per cent of its range of abundance) between about 4.1-4.4 log MPN. The data in Figure 11 represent all stations throughout the area where these species were taken because these species were not restricted to specific communities.

There were three 3rd order species in the spermatophyte zone community. Figure 12 shows that unusual abundance of the suspension feeder *Chione cancellata* was restricted to a range of about 3.9-4.8 log MPN, and that the long-siphoned deposit feeder *Tagelus divisus* was unusually abundant between about 3.2-4.8 log MPN. *T. versicolor*, a 3rd order species in both communities, has already been considered in Figure 11.

Similar treatment of the data on *O. limicola* is included in Figure 12 for three reasons: (1) unlike all other common species, its maximum abundance occurred in the softest sediments of the area; (2) it was sharply limited by oxidizable organic content of the sediment, measured by oxygen uptake; and (3) while tolerant of high MPN, it was most abundant in medium to low MPN areas.

FOULING ORGANISMS

Ecological factors favoring heavy fouling in northern Biscayne Bay were first recognized and listed by Weiss (1948), who compared the fouling complex along the Miami Beach shoreline with that several miles south of Rickenbacker Causeway. Factors which he listed included pollution, abundance of pilings and sea walls, little mixing of bay water with ocean water, and strong tidal currents. More stations were studied by Smith *et al.*, (1950), who found that the greatest amount of initial attachment and greatest subsequent growth occurred in the northern part of the bay. These authors also showed that plankton counts and chemical nutrients were higher north of Venetian causeway than south of it. Similar results were reported previously from this study (McNulty *et al.*, 1960), which showed that components of both phosphorus and nitrogen, and zooplankton volumes, were higher in polluted areas than in unpolluted water to the south.

The displacement volumes of material collected on subtidally exposed glass panels at 15 stations were measured from January through August, 1955. Because the highest volumes were coincident with the occurrence of thick mats of amphipod tubes, a record of

TABLE 4

MEAN DISPLACEMENT VOLUMES OF FOULING ORGANISMS AND MEAN NUMBERS OF AMPHIPOD TUBES ON GLASS PANELS EXPOSED SUBTIDALLY FOR ONE MONTH (JAN.-AUG., 1955)

Station	Displacement Volume (ml./dm. ²)	Amphipod Tubes (No./dm. ²)	Number of Observations
8	10.7	211	6
88	10.8	258	7
304	6.9	121	8
401	12.1	403	4
406	2.8	31	8
16	2.3	287	4
605	0.9	32	6
608	0.7	4	8
610	1.1	15	7
703	0.6	49	5
20	9.3	138	8
708	4.9	2	7
710	5.8	24	7
801	4.0	179	5
66	0.4	34	6

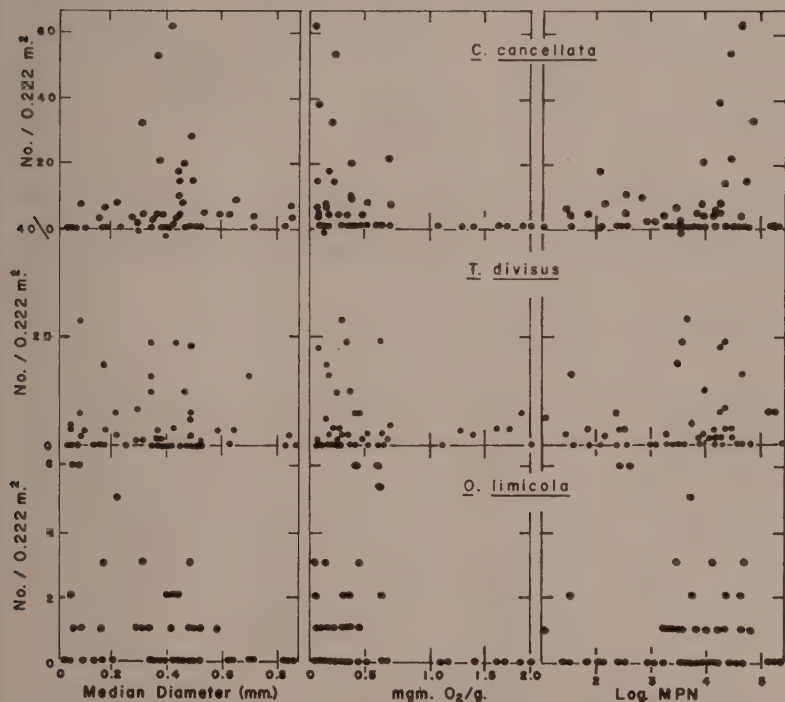


FIGURE 12. Scatter diagrams of the abundance of two 3rd order characterizing species of the spermatophyte association (*C. cancellata* and *T. divisus*) and of the characterizing species of the anomalous, no fixed vegetation zone, *O. limicola*. Abscissas represent median grain diameter, oxygen uptake of sediments, and log. MPN.

counts of the number of tubes on all panels was kept as well. Results are summarized in Table 4. The disappearance of panels was a recurring problem, certainly at least in part due to the activity of curious boatmen, with the result that a record of eight recoveries for eight exposures was attained at only four stations. The horizontal distribution of fouling volumes, shown in Figure 13, was maximal along the Miami shoreline north of Venetian Causeway, an area characterized by: (1) rich mineral nutrients and zooplankton, (2) practically no tidal flushing, *i.e.*, little or no net movement of bay water seaward on each tidal cycle, (3) an abundance of pilings and seawalls, and (4)



FIGURE 13. Horizontal distribution of mean displacement volumes of fouling organisms, glass panel experiments.

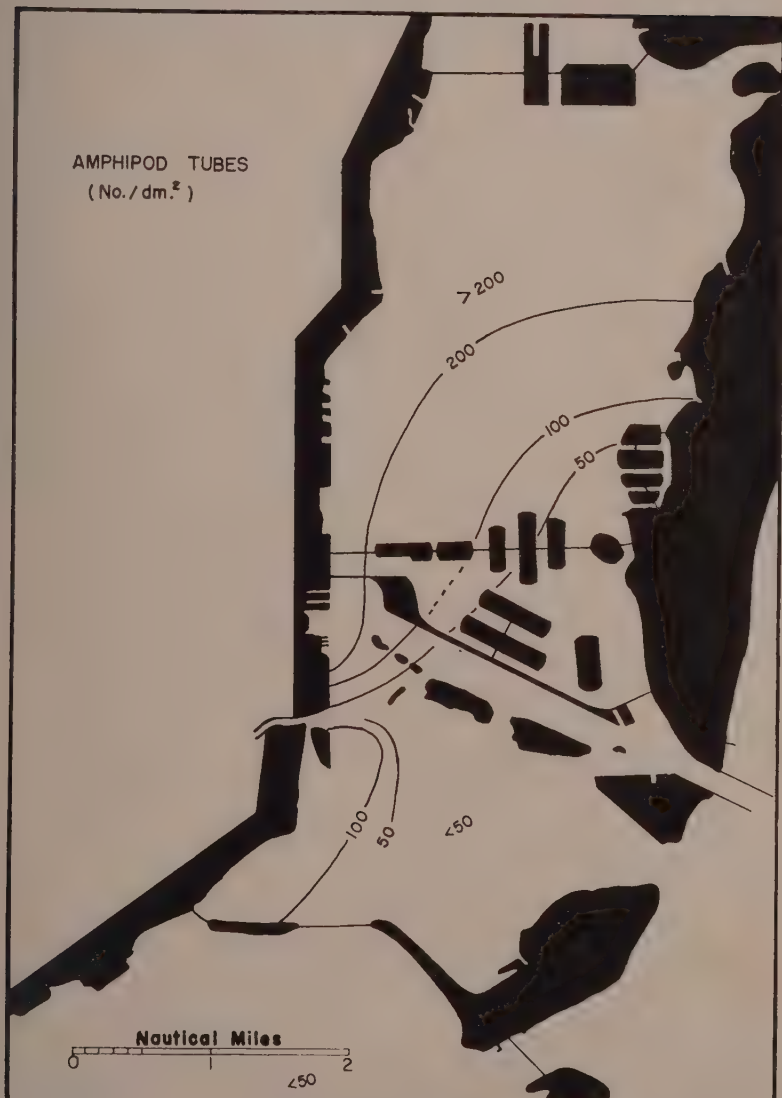


FIGURE 14. Horizontal distribution of mean counts of amphipod tubes, glass panel experiment.

brown-colored, turbid water, high in oxygen content and never below 20‰ salinity, a similar habitat to that found favorable for the growth of tubiculous amphipods in Los Angeles-Long Beach harbors (Barnard, 1957). The figure shows that high fouling volumes were not found uniformly throughout polluted areas. In Government Cut, for instance, volumes remained relatively low. An important reason for this is, probably, that the main channel for net movement of river water (and the larvae of fouling organisms) seaward is in Government Cut and vicinity, Station 66 south of Rickenbacker Causeway showed uniformly low volumes.

The distribution of amphipods is of special interest because of their association with some polluted parts of the area. The horizontal distribution of mean tube counts is shown in Figure 14. The isolines do not follow the pattern described by MPN (Figure 2) but instead reflect primarily the hydrography of the area. Although occurring in greatest numbers along the Miami shoreline, where MPN was maximal, high counts also were obtained at Station 88 along the Miami Beach shoreline where MPN was relatively low. Conversely, low abundance of amphipod tubes occurred in Government Cut where MPN counts were high.

The major species of amphipods taken from panels in the study area were: *Erichthonius brasiliensis* (Dana), *Corophium acherusicum* (Costa), *Elasmopus pecteniscus* (Bate), *Podocerus brasiliensis* (Dana), and *Grubia filosa* (Savigny). Two of these, *E. brasiliensis* and *C. acherusicum*, are major species in Los Angeles-Long Beach harbors (Barnard, 1957) where they were most abundant in waters having high turbidity coincident with favorable dissolved oxygen and temperature conditions.

As a check on the above results, an experiment on initial attachment of dominant fouling organisms using surveyor's stakes planted at 57 locations was conducted in mid-September, 1956. Location of the stakes coincided with hydrographic stations and included locations between the 15 stations used in the glass panel tests. Counts were made of the abundance of amphipod tubes, algae (*Enteromorpha flexuosa* Wulfen) and *Ulva lactuca* Linnaeus var. *rigida* (C. Agardh), and barnacles (*Balanus improvisus* Darwin). The results are shown in Figures 15, 16, and 17. The distribution of tubiculous amphipods (Figure 15) was sharply limited to the Miami shoreline north of the Miami River mouth and east about one-half mile into Government Cut. This distribution delimited rather precisely areas of high pol-

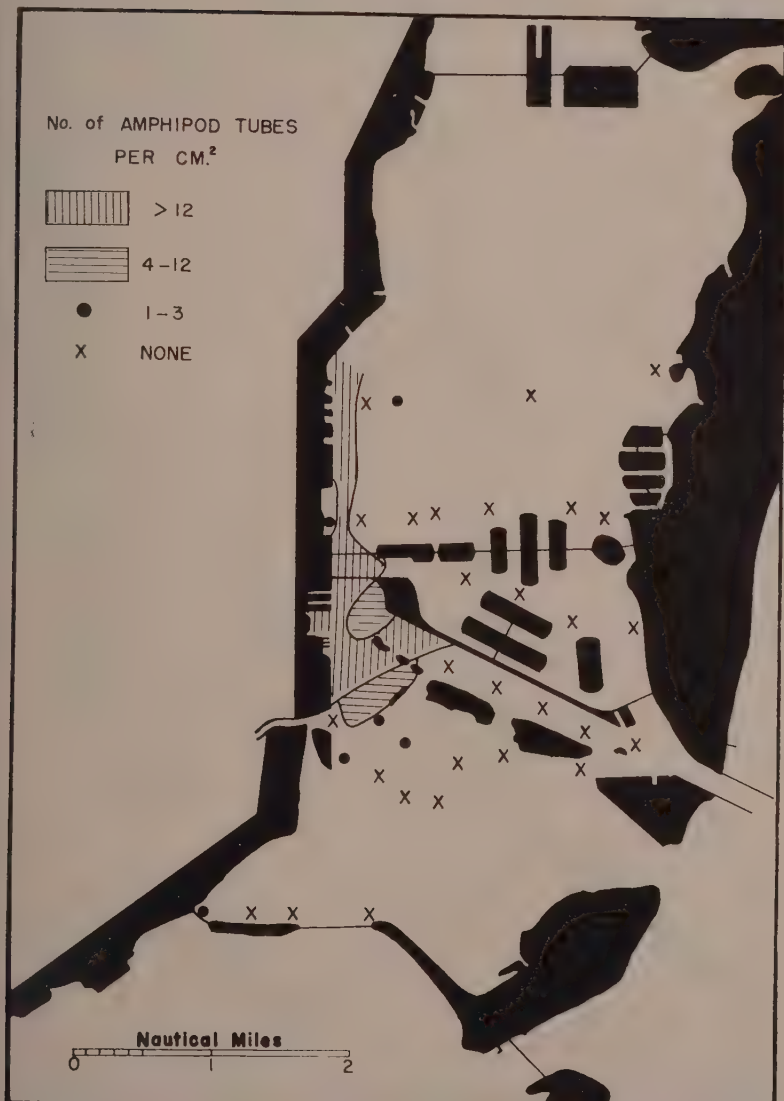


FIGURE 15. Horizontal distribution of amphipod tubes, stake experiment.

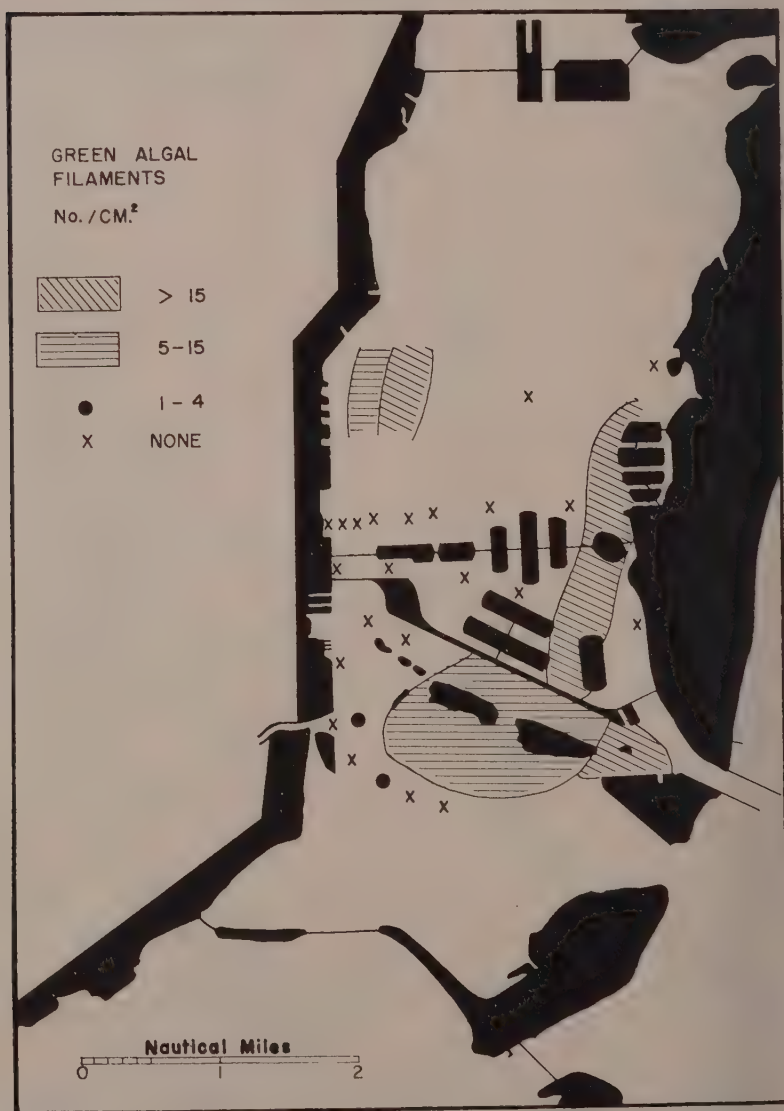


FIGURE 16. Horizontal distribution of green algal filaments, stake experiment.

lution north of the river but failed to indicate the distribution of sewage south of the river. Thus, under conditions of the test and in areas where hydrographic and other factors were favorable for their occurrence, the tubiculous amphipods occurred only where mean log MPN greater than 4.3 was found. In striking contrast, the algae attached in intermediate abundance (5 to 14 individuals per cm.²) only where mean log MPN less than 4.3 was found. This distribution pattern seems to correspond with gradual clearing of the turbid, polluted waters but no quantitative data are available for numerical comparisons. Unlike both of the above groups, the initial attachment of barnacles was unrelated to pollution. Figure 17 shows that comparable abundance occurred along both Miami and Miami Beach shorelines. Both areas are characterized by many pilings and seawalls and by strong tidal current which would facilitate the advection of larvae to the stakes. The mid-bay area north of Venetian Causeway, lacking both of the above characteristics, showed low initial attachment.

SUMMARY AND CONCLUSIONS

In this study of benthic and fouling macro-organisms, evidence on the following three aspects of ecological effects of sewage in Biscayne Bay have been described: (1) harmful effects, (2) fertilizing effects, and (3) indicator organisms of both (1) and (2).

1. Harmful effects, as indicated by absence of life, were limited to 3 of 65 stations. All three stations were within 200 yards of sewage outfalls, they were in greater than average depth, and they were characterized by soft, sticky mud having high contents of oxidizable organic matter. Complete lack of spermatophytes at many stations in the polluted area may be the result of sewage, although the effects of dredging, lowered salinity and brown colored, relatively turbid water may be of equal importance.

2. Fertilizing effects were pronounced. Many species of both the attached vegetation and benthic animals showed this response as measured by their abundance per unit area of bottom. The effects were most pronounced in a narrow band roughly 200 to 600 yards from sewage sources in shallow water with good tidal circulation where the bottom consisted of firm sandy mud (median grain diameter 0.125 to 0.500 mm.).

3. Indicator organisms of both harmful and fertilizing effects were

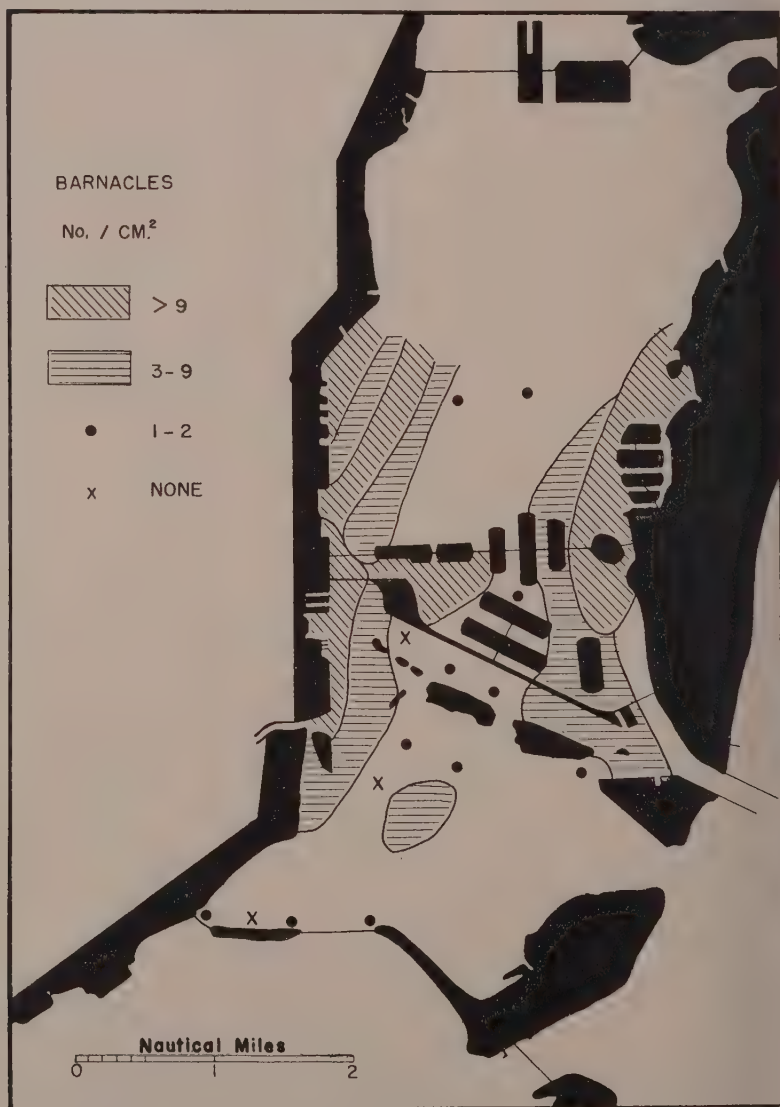


FIGURE 17. Horizontal distribution of barnacles, stake experiment.

present. Using in part the principles for describing bottom communities developed by Thorson (1957), two plant-animal associations were found to occupy distinct benthic zones, one primarily in highly polluted areas and the other primarily in less polluted areas. These were characterized, respectively, as the *Gracilaria blodgettii* and/or *Agardhiella tenera* plus *Diopatra cuprea* community and the *Halophila baillonis* and/or *Diplanthera wrightii* plus *Amphioplus abditus* community. Second order characterizing species of the red algal community were found to indicate high MPN better than the other characterizing species. The third order characterizing species of both communities responded markedly to fertilizing effects of sewage as shown by their unusual abundance adjacent to the most highly polluted parts of the bay.

The dominance of tubiculous amphipods on glass panels exposed for one month was the major characteristic of the fouling complex in highly polluted areas. However, these organisms as a group occurred abundantly elsewhere in relatively unpolluted areas. Shortening the time of exposure to two weeks and changing the method of collection from glass panels to surveyor's stakes planted in the sediment, their appearance in abundance was limited to areas of high pollution (MPN greater than 10,000). The two species found most frequently were *Erichthonius brasiliensis* and *Corophium acherusicum*.

Sediments have been analyzed with respect to their median grain diameter, sorting coefficient and oxygen uptake measured in the Warburg respirometer. Unusually high oxidizable organic content was limited to 7 of 65 stations, five of which had median diameters of less than 0.100 mm.

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NOTES ON THE BIOLOGY OF THE GOBIID FISH *SICYDIUM PLUMIERI* IN PUERTO RICO

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ABSTRACT

Seven synonyms of *Sicydium plumieri* (Bloch) are listed and vernacular names for this species of goby at various West Indian islands are given. Adults of *S. plumieri* live in freshwater. They are strong swimmers, and their ventral sucking disk enables them to cling to rocks in swiftly moving water. The young can move up a vertical wet surface. In the rivers and streams this goby feeds by grazing slime algae such as desmids from stones. It can change its color rapidly from black to pale tan to match its background; it is usually dark because dark rocks predominate in the natural habitat. Differences between the sexes in shape of genital papilla, width of head and body, and height of fins are noted. Males exhibit bright nuptial colors from May to October, and have been observed in apparent display of this color to females from pinnacles of rocks in stream beds. Gravid females were collected in April, June, and July, but no eggs have yet been found laid beneath rocks in streams. Postlarvae migrate upstream from the sea in enormous numbers from July through January; the largest runs occur from September to November. The runs last about 2 days and begin from one to two days after the third quarter phase of the moon. The postlarvae collected in the sea have higher, more compressed bodies and average 3 mm longer than river fish. Sea postlarvae are transparent and usually scaleless when they start their migration upstream. Soon after entering the river, dark bands appear on the body. Scales first appear on the caudal peduncle of the slightly shrunken river migrant and develop progressively forward on the body. Shortly after the young settle to the bottom, the tail alters from emarginate to truncate, and becomes rounded with further growth. The banded color pattern becomes less intense after a size of 30 mm total length is reached and disappears entirely by a length of 40 mm. The postlarvae are preyed upon heavily by terns, snooks, grunts, and large gobioid fishes such as *Gobiomorus* and *Eleotris*. The young, which are regarded as a delicacy in the West Indies, are of commercial importance.

INTRODUCTION

The gobiid fish, *Sicydium plumieri* (Bloch), lives as an adult in freshwater in the West Indies where it attains a total length of about five inches. Like most other gobies, its ventral fins are united to form a rounded sucking disk. This disk enables the goby to cling to rocks in fast water. It can cling to a rock with such force that it is very difficult to dislodge. It grazes algae from the smooth surfaces of rocks and boulders in streams. Postlarval gobies of this species enter river mouths from the sea in enormous numbers and move gradually upstream to the headwaters. The postlarvae are collected by fishermen with dipnets for food.

The author first became acquainted with this goby in Puerto Rico in 1945. During a cruise in 1946 on Richard H. Bertram's sloop "Sora" from Puerto Rico to the Grenadines, data on *S. plumieri* were collected at Martinique, Guadeloupe, Dominica, and St. Vincent. Subsequently, research has been conducted on this fish in Puerto Rico.

ACKNOWLEDGEMENTS

A considerable part of this work has resulted from studies sponsored by the Federal Aid (Dingell-Johnson) Program for sportfishery research and development in Puerto Rico. A large amount of data was collected on the habits of *S. plumieri* during the biological survey of the Añasco River in 1955 and 1956. The author was ably assisted in this survey by Herbert A. Zalduondo, now the superintendent of the Government Fish Hatchery at Maricao.

The writer wishes to express his appreciation for help over the years from Félix Iñigo, chief of the Fish and Wildlife Section of the Government of Puerto Rico, and Buenaventura Quiñones Chacón, former chief of the same section. The writer is indebted to Dr. Virgilio Biaggi, Jr., Director of the Biology Department of the College of Agriculture and Mechanic Arts, University of Puerto Rico for providing assistance and collecting materials, to Dr. Juan A. Rivero, Director of the Institute of Marine Biology, for facilities at the Laboratory at Magueyes Island, La Parguera, to Dr. David K. Caldwell of the Los Angeles County Museum for his notes on *Sicydium* from Jamaica and his help with the literature, and to Mr. Ventura Barnés, Jr., former biologist of the Fish and Wildlife Section, Mr. Stephen Haweis of Sylvania, Dominica, Dr. Paul Lodeon of Fort-de-France, Martinique, Mr. Adrien Questel of Pointe-a-Pitre, Guadeloupe, and Mr. Bernard Lewis of the Institute of Jamaica at Kingston for collections and data.

The writer thanks Dr. John E. Randall for his work in the careful revision of this manuscript.

SYNONYMY

Sicydium plumieri exhibits considerable change in color and morphology during its movement from the sea to freshwater and in its transformation from the postlarval to juvenile form. As an adult the sexes show marked differences. It is not surprising, therefore, that the species has been described several times. The synonymy follows:

- Gobius plumieri* Bloch, 1786, Ichthy., p. 125, pl. 178, fig. 3 (Martinique, from a drawing by Plumier).
- Sicydium siragus* Poey, 1861, Memorias, 2: 278 (Santiago de Cuba).
- Sicydium antillarum* Ogilvie-Grant, 1884, Proc. Zool. Soc. London, p. 157 (Barbados).
- Sicydium punctatum* Perugia, 1896, Annali del Museo Civico di Storia Naturali di Genova, ser. 2, 16: 18 (Martinique).
- Sicydium vincente* Jordan and Evermann, 1898, Bull. U.S. Natl. Mus., 47 (pt. 3): 2207 (St. Vincente, W.I.).
- Sicydium caguitae* Evermann and Marsh, 1902, Bull. U.S. Fish Comm., 20: 18, 291-292, fig. 89 (1900) (Puerto Rico).
- Sicydium buscki* Evermann and Clark, 1906, Proc. U.S. Natl. Mus. 30: 854, fig. 3 (San Francisco Mountain, Santo Domingo).
- Gobiosoma thomasi* Fowler, 1949, Notulae Naturae, 218 (Rio Grande, Portland, Jamaica).

The author agrees with Hildebrand (1935) that *S. caguitae* is the female of *S. plumieri*.

Fowler's type of *Gobiosoma thomasi* is 27 mm in total length. The drawing shows an emarginate tail which is characteristic of the migrating postlarva of *Sicydium*. Scales do not appear on *S. plumieri* at a uniform size, and a 27 mm fish may have some scales or may lack them, as is apparently the case with *thomasi*. Twenty topotypes of *thomasi* were seen by the author at the Institute of Jamaica.

Specimens of *Sicydium plumieri*, examined by the writer, are on deposit at the United States National Museum, Washington, D. C., the Institute of Marine Science, University of Miami; University of Florida at Gainesville; Institute of Jamaica at Kingston; College of Agriculture and Mechanic Arts at Mayagüez, Puerto Rico; and Institute of Marine Biology at La Parguera, Puerto Rico.

VERNACULAR NAMES

In Puerto Rico, *Sicydium plumieri* is known as an adult by the name of "olibo" or "chupa piedra" (rock sucker); the latter name is applied on occasion to other freshwater gobies. The name for the transparent postlarvae as they enter the river mouths is "setí," a name sometimes applied to other small bait fishes.

The Cuban name is "sirajo" (Duarte-Bello, 1959:124), from which Poey's *S. siragus* and "sirago" of Jordan, Evermann, and Clark (1930) are derived.

In Jamaica, the name "ticky-ticky" is applied to the young fishes according to Townsend (1895?) "Ticky" probably refers to the ability of these fishes to stick to objects.

Marceau J. Edouard, fishery officer of Haiti, has examined some of the writer's specimens. He says this fish is known as "tilagal" from Riviere Jean Rabel, at Môle St. Nicolas, Haiti.

Some names used in the Lesser Antilles are as follows: "titiri" at Martinique and Dominica; "tri-tri" at St. Vincent; and "tiri-tiri" or "pisquettes" at Guadeloupe. The various spellings of "titiri" are presumably derived from an original name which is said to be of Carib Indian origin. The "i" is pronounced as the vowel "e" in the English "be".

The author proposes the English common name "sirajo goby" for this fish.

FOOD HABITS

Sicydium plumieri feeds by scraping algae from hard bottom in streams. Its mouth parts are well adapted to grazing slime algae such as desmids off the surface of rocks and stones in the fast-moving water. The upper jaw contains a single row of fine setiform teeth, the lower jaw one row of five separate villiform teeth on each side. There is a forward-pointing, cartilaginous, ridge-like structure in the front of the lower jaw which probably aids in scraping algae off the rock surfaces. As is typical of a herbivore, the intestine is long and coiled.

SEXUAL DIMORPHISM

Morphological differences in the sexes of *Sicydium plumieri* are summarized in the table below. They are most pronounced in large individuals.

<i>Character</i>	<i>Male</i>	<i>Female</i>
genital papilla	simple and pointed	wide with lengthwise median depression
width of head	narrow	wide
greatest width of body	slim	wide behind pectoral fins
first dorsal fin	rays long and produced	rays slightly produced in large females only
anal fin	high	fin lower

In addition, the males display nuptial colors (see next section).

COLORATION

When the postlarvae of *Sicydium* are collected in the sea they are transparent, with greenish iridescent eyes, and viscera that appears as

a red and silver ball. When crowded together in quantity they exhibit a light reddish hue. Soon after entering the rivers dark bands form. There are seven on the body and two on the tail. After a size of about 30 mm in total length is reached, the banding becomes less intense. It may disappear entirely before a fish attains 40 mm. Those 40 mm or more in length have all lost their bands.



FIGURE 1. *Sicydium plumieri* (UMML 8464). Upper: Male, 86 mm Standard Length; Lower: Female, 88 mm Standard Length, Río Guaba, Puerto Rico. Photograph by J. E. Randall.

Sicydium can change its color rapidly to match the background. Although the fish may vary from light tan to black, they are usually dark because black rocks predominate in the streams.

From May to October males from the size of 35 to 40 mm in total length and larger take on brilliant iridescent blue-green hues on the head, especially the opercle. The bases of the dorsal and anal fins are marked with a dark reddish stripe. In males of 100 mm or more the fins become opaque white and are thickened, and the body is pale blue. Females are usually uniform dull gray or brown. Both sexes have a prominent red blood vessel at the anterior edge of the ventral sucking disk.

REPRODUCTION

On a number of occasions, especially in July, the author has observed color display of males. Brightly colored males seek the pinnacles of rocks on the stream bed, cock their white tails at an angle, and often remain motionless for several seconds. The duller-colored females tend to feed lower down on the rocks and do not appear to pay attention to the males. In correspondence to the author, Dr. Caldwell mentioned seeing a "white (*Sicydium*) 'flash' its pectorals several times" in a stream at Bath Fountain, tributary of Sulfur River, Jamaica, June 20, 1957. This movement of the pectoral fins, which the author has also observed, helps attract attention to the male. It is possible that this color display of males has significance in nuptial activities.

Hildebrand (1935) recorded one gravid female *S. plumieri* among 13 adults collected from February 16 to March 12, 1934. The author has collected gravid females in April, June, and July. Adults from three to four inches in standard length have large ovaries and yellow ova 0.2 mm in diameter. To date the author has not found males with ripe testes and running milt.

Manacop (1953) stated that the eggs of the Philippine goby *Sicyopterus extraneus* Herre are laid on the under surface of rocks in freshwater, and the newly-hatched larvae of 1.5 mm are presumably washed to the sea during the floods of the rainy season. They return to the river mouths about a month later to start their upstream migration. At this time they average about 26 mm, a similar size to *Sicydium* at this stage. *Sicyopterus*, recorded also from Japan, Samoa, and the Society Islands, appears closely related to *Sicydium*, and the life histories of the two genera may be expected to be similar.

In spite of five years of turning over rocks in streams of Puerto Rico, the author has not yet found the eggs of *Sicydium*. Possibly they are laid under large boulders in deep and fast water where the physical difficulties of collection would be very great.

UPSTREAM MIGRATION OF POSTLARVAE

The postlarval sirajo gobies migrate upstream from the sea in Puerto Rico in enormous numbers from July through January. The largest runs occur from September to November. River fishermen know that the runs start from one to two days after the third or last quarter phase

of the moon. An average run lasts about two days.

Mr. Zalduondo and the author observed a continuous column of migrating gobies at Puente Oveja, about 6 miles above the mouth of the Añasco River on November 15, 1955. By November 26, the gobies were at the Remolino above El Guacio, a distance of 18 river miles.

On December 16, 1955, a column of migrating gobies was seen at Puente Espino, one mile upstream from Puente Oveja. The column was estimated to be six inches wide and about $2\frac{1}{2}$ rows of fishes in depth. An estimate of 300 gobies pass a given point in one second; or at least 500 per second when there is one column on each side of the river. Thus an average migration of 50 hours would account for about 90,000,000 fish.

There seems to be a definite shrinkage after the postlarvae enter the rivers from the sea. Sea postlarvae collected on November 24, 1959, averaged 27 mm total length. River mouth postlarvae collected on September 26 and 27, 1959, did not much exceed 24 mm total length. Furthermore, there is a change in the shape of the body. The sea postlarvae are laterally compressed, whereas the river fish have less body depth and are more rounded.

The postlarval gobies are usually scaleless when they are in the transparent stage about to migrate up the rivers. Scales first appear

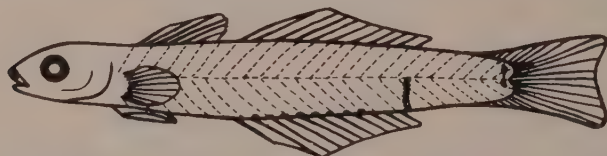


FIGURE 2. *Sicydium plumieri* (UMML 8633). Juvenile, 21 mm Standard Length, mouth of Río Añasco, Puerto Rico. Drawing by Helen A. Randall.

on the caudal peduncle at about 20 mm standard length on the slightly shrunken migrant after it has entered the river. By 21 mm, fishes may be scaled to the level of the anterior part of the second dorsal fin, and by 22 mm they may have scales at the level of the anterior part of the first dorsal fin. Most of the fish are nearly fully scaled by 25 mm standard length (27 to 28 mm total length) except for the belly and the head. Squamation of the belly is complete on adults over 70 mm in length; the head remains naked throughout life. The scales are ctenoid and have a ridged appearance under a microscope.

The postlarvae have a characteristic emarginate caudal fin. Shortly after they settle to the stream bottom, the tail becomes truncate. With growth it gradually becomes rounded.

ECONOMIC IMPORTANCE

The postlarvae are a food delicacy in the West Indies. The city of Arecibo, Puerto Rico, is known for its "empanadas de setí," which consists of the young gobies fried with plantains.

When the "setí" are about to enter the river on their upstream migration from the sea, fishermen try to catch them in burlap bags with a wooden hoop. Large flocks of terns help to indicate where the heavy concentrations of setí are. The fish are collected in five-gallon lard cans which hold about 40 pounds of fish when full. The wholesale price is about \$2.00 per can.

From a single migration up the Añasco River, older fishermen say that as many as 500 cans of setí have been collected. In September, 1959, an estimated 50 cans were collected. Fishermen in general believe that the runs are considerably less than during former years.

The young of *S. plumieri* can move up a vertical wall, such as a dam, providing the surface is wet. Nevertheless, it is believed that dams in Puerto Rico have materially reduced the number of gobies in the freshwaters of the island.

During the upstream migration, the postlarvae are preyed upon almost continuously by snooks, grunts, and large gobioid fishes such as *Gobiomorus* and *Eleotris*.

The oil content of *Sicydium* is high. Fat bodies are often found in adults. About 100 adults from three to five inches in length preserved in formalin in a gallon jar will produce about one-quarter inch layer of yellow-brown oil at the surface.

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OBSERVATIONS ON *PHORONIS ARCHITECTA* IN FLORIDA WATERS

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ABSTRACT

The known distribution of *Phoronis architecta* in Florida waters is extended from Alligator Harbor to Miami. Sections have been prepared to show that all phoronid populations sampled belong to this solitary sand-dwelling species. Densities of 45/sq. ft were found. The breeding season at Alligator Harbor is at least from February to December.

INTRODUCTION

In a recent paper Long (1960) identified Alligator Harbor phoronids as *Phoronis architecta* Andrews and thus has contributed the first positive identification of an adult phoronid from the Gulf of Mexico. Her identification was ultimately based on counts of the longitudinal muscle bundles, the only method of positively separating this species from the very similar *P. psammophila*. Marsden (1959) has presented a case for the need of more data on variation and geographical distribution in the phylum.

The present note confirms this identification and adds additional information about the distribution and variation of *P. architecta* along the south and west coasts of Florida. Information is also presented on the habitat occupied throughout the distribution, and the breeding season at Alligator Harbor. Collection of individuals was greatly facilitated by use of the Florida State University Marine Laboratory at Alligator Harbor, Franklin County, Florida.

DISTRIBUTION

On the East Coast *P. architecta* continues to be taken only near Cape Hatteras and the Beaufort region, the type locality. However, in addition to Alligator Harbor (Long, 1960) the author found the species extensively along the Gulf Coast of Florida, and in Biscayne Bay. Figure 1 indicates the known extent of this species' range in peninsular Florida waters. The negative evidence along the East Coast from St. Augustine south to N. Miami may be the result of sampling in unfavorable habitats. The lack of *P. architecta* from the pure calcareous bottoms in the Keys is more likely to be of some biological meaning since at none of the six areas sampled were the waters diluted or polluted, or the bottoms churned up by heavy motorboat

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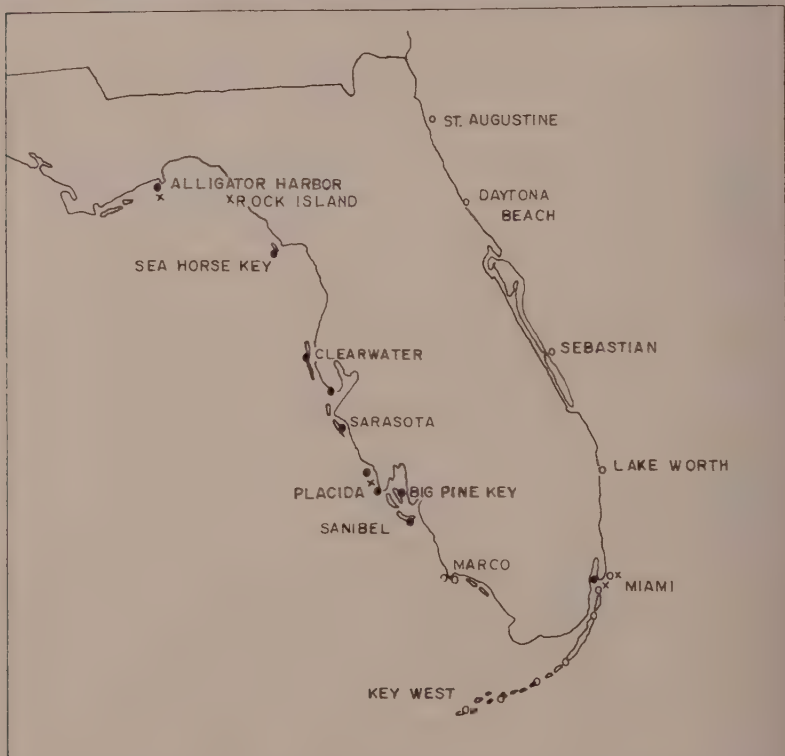


FIGURE 1. Map of Florida with stations at which *Phoronis architecta* was (●) or was not (○) collected indicated. The symbol x denotes known occurrence of actinotrochs, including records from Davis (1950).

traffic as it is along the east coast. The most obvious difference between the Keys and the quartz sand bottoms of western Florida where *Phoronis* is common, and often abundant, is the character of the bottom sediment.

Collections were made during the winter of 1959 and the spring of 1960 from the -4.0 foot datum to above mean low water. Table 1 summarizes the data on location, relative abundance, immediate habitat, and consorts. Abundance figures are based on the number per sq. ft. of the characteristic tubes. These are easily distinguished in the field from sand tubes of the polychaete *Onuphis* sp. by their

rigid form and coarser sand grain composition. The term uncommon indicates less than one per sq. ft., common indicates that densities of 5-20/ sq. ft. were encountered, and abundant includes figures in excess of this amount. The consort column is a phylogenetically arranged species list of the animals most conspicuously present at each locality.

TABLE 1

DESCRIPTION OF PHORONIS LOCALITIES FROM FLORIDA WATERS.

Location	Abundance	Immediate Habitat	Consorts
Biscayne Bay	Uncommon. 1 animal in 2 hours of collecting.	Hard bottom of mixed calcareous and quartz sand with <i>Cymodocea</i> and <i>Diplanthera</i> .	<i>Dendrostomum</i> sp. <i>Diopatra cuprea</i> <i>Glycera dibranchiata</i> <i>Onuphis</i> sp.
South tip of Sanibel Island	Uncommon.	Bottom of coarse shell and sand. No grass. Well scoured by current.	<i>Nassarius vibex</i> <i>Axiothella mucosa</i>
Big Pine Key, near Ft. Myers	Uncommon. 4/10 sq. ft.	Bottom of fine quartz sand.	<i>Tagelus divisus</i> <i>Lucina floridana</i> <i>Onuphis</i> sp.
Stump Pass, Englewood	Abundant.	Bottoms of fine sand or <i>Diplanthera</i> . Well washed by currents, though protected from wave action.	<i>Ceriantheopsis americanus</i> <i>Glottidia pyramidata</i> <i>Nassarius vibex</i> <i>Ensis minor</i> <i>Venus campechiensis</i> <i>Onuphis</i> sp.
Placida and Sarasota	Uncommon.	Protected by growth of <i>Diplanthera</i> . Some accumulation of organic matter.	<i>Branchiostoma caribaeum</i> <i>Glottidia pyramidata</i> <i>Venus campechiensis</i> <i>Ampeliscus holmesi</i>
Clearwater Beach and St. Petersburg	Common.	Bottom of coarse shell and sand. No grass. Well washed but protected from wave action.	<i>Glottidia pyramidata</i> <i>Nassarius vibex</i> <i>Onuphis</i> sp. <i>Branchiostoma caribaeum</i>
Sea Horse Key	Uncommon.	Bottom of <i>Diplanthera</i> Exposed to wave action.	No data taken.
Alligator Harbor	Abundant. 2-45/sq.ft.	Bottoms of sandshell or <i>Diplanthera</i> . Exposed or protected from wave action.	<i>Glottidia pyramidata</i> <i>Fasciolaria hunteria</i> <i>Nassarius vibex</i> <i>Busycon contrarium</i> <i>Ensis minor</i> <i>Cistenides gouldii</i> <i>Ampeliscus holmesi</i>

Habitats supporting phoronid populations appear to have the following in common. All the habitats were sand or mixtures of coarse shell and sand, and without excessive accumulations of organic detritus. Phoronids were never found in areas of soft bottom sediment indicative of little effective current action. The presence of the rooted aquatic *Diplanthera wrightii* and its stabilizing effect on the bottom (Humm, 1956) allows *P. architecta* to extend into areas of fairly heavy surf action. The consorts are significant in that they are indicative of sandier, rather than muddier, bottoms. All habitats are exposed at some stage of spring low tides, with the possible exception of the Biscayne Bay station, indicating the temporary exposure does not affect local distribution.

SPECIFIC IDENTIFICATION

Individuals from Miami, Stump Pass (Englewood), Sea Horse Key, and Alligator Harbor were sectioned and stained in Harris' hematoxylin and eosin to allow a direct count of muscle bundle number per coelomic quadrant. The composite muscle bundle formulae, and the range in total numbers of muscle bundles, as explained in Marsden (1959:92) are given below, as are Andrews (1890) and Long's (1960) counts for comparison.

Biscayne Bay (1 individual)	$\frac{13}{6} \mid \frac{15}{6}$	40
Stump Pass (7 individuals)	$\frac{13-15}{6-7} \mid \frac{12-14}{6-7}$	39-42
Sea Horse Key (3 individuals)	$\frac{14}{7} \mid \frac{13-15}{6-7}$	40-43
Alligator Harbor (2 individuals)	$\frac{13}{7} \mid \frac{12}{6}$	38
Alligator Harbor (4 individuals)	$\frac{12-13}{6-7} \mid \frac{12-13}{6}$	
Long (1960)		
Beaufort, N.C.	$\frac{13}{4-9} \mid \frac{12-16}{5-6}$	
Andrews (1890)		

These data show that along the southeast coast of the United States *P. architecta* has a high degree of internal consistency with respect to the number of longitudinal muscle bundles. In addition the single large nerve fiber near the base of the left lateral mesentery, another characteristic of *P. architecta*, was noted in most individuals. Other

similarities among the Florida populations include the structure of the tube, maximum individual size, and the general form of the lophophore.

BIOLOGICAL OBSERVATIONS

Typical actinotroch larvae, presumably those of the species under discussion, were taken in plankton tows at Alligator Harbor on 7 December 1959 and from the middle of February to August 1960, when towing was discontinued. Adult specimens secured during November 1959 had ova floating in their coelomic spaces, indicating a long breeding season, if not a continuous one, at Alligator Harbor. Information substantiating this conclusion is found in Davis (1950). He collected actinotrochs, presumably of *P. architecta*, in December 1947 from Rock Island (see map) and in September 1947 from two stations in the immediate vicinity of Miami. Hedgpeth (1954) also records the presence of actinotrochs during the winter months in the neritic waters of Louisiana and Texas.

The greatest concentration of phoronids observed at Alligator Harbor was directly opposite the marine laboratory on the shelly shoulder of an oyster reef. Here, in the shallow bottom, densities of up to 45/sq. ft. were found. On the sandbar crossing the mouth of this neutral estuary densities of from 2-6/sq. ft. were encountered. These latter densities are close to the figure of 4-6/sq. ft. calculated from Brooks and Cowles (1905) for *P. architecta* at Beaufort, and the 2/sq. ft. indicated by Long (1960) for Alligator Harbor samples. Along the Gulf estimated densities of from 10-30/sq. ft. were encountered with regularity, although exact density measurements were not made at all stations.

On the basis of these observations, Gulf Coast biologists can expect to discover considerable concentrations of the solitary phoronid, *P. architecta*, in shallow, sandy bottoms.

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The scope of the bibliography is limited in general to the area which includes the southeastern United States, the Gulf of Mexico, and the Caribbean, but papers of more general interest may be listed in cases where they have some special significance to the area.

The degree of comprehensiveness of the bibliography is to a large extent dependent upon the cooperation of workers in the Marine Sciences of this area. *It is therefore hoped that individuals and organizations will aid by sending copies of all relevant publications to the Editor.* Any omissions brought to the attention of the Editor will be included in subsequent issues.

It has been found convenient to use a modification of the classification used by the Journal du Conseil Bibliography for present purposes.

The Editorial staff wishes to acknowledge the valuable assistance given by a number of investigators in compiling the bibliography.

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ERRATUM

In Bull. Mar. Sci. Gulf & Carib., 11 (1) the legend for figures 32-34 should read *Tetrastemma worki*, new species, instead of *Tetrastemma bobi*, new species.

